STUDY ON ABNORMAL LACTATION LENGTH IN MURRAH BUFFALOES

Thesis

Submitted to Guru Angad Dev Veterinary and Animal Sciences University in partial fulfillment of the requirements for the degree of

MASTER OF VETERINARY SCIENCE
in
ANIMAL GENETICS AND BREEDING
(Minor Subject: Animal Biotechnology)

By

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CERTIFICATE – I

This is to certify that the thesis entitled, **"STUDY ON ABNORMAL LACTATION LEGTH IN MURRAH BUFFALOES"** submitted for the degree of **M.V.Sc.** in the subject of **Animal Genetics and Breeding** (Minor Subject: **Animal Biotechnology**) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Sylvia Lalhmingmawii (L-2019-V-05-M)** under my supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE - II

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ABSTRACT

The purpose of this study was to determine the causes and risk factors of lactation length variation, to estimate the consequences of abnormal lactation length on performance traits and assess its impact on genetic parameters. A total of 1235 lactations from 470 animals were recorded along with the possible risk factors capable of causing lactation length variation. The overall lactation length in Murrah buffaloes was found to be 295.886 ± 3.420 days. The lactation period was divided into 5 categories i.e., extremely short, short, prolong and extremely prolong based on Mean±SD. Abortion, stillbirth, and udder swelling were identified to induce short lactation length, whereas repeat breeding, retention of placenta, dystocia, lameness, and udder wound were found to have an impact on prolonging lactation length. Abnormal lactation length was also found to have an impact on the important traits of both the current and following lactation cycle. Two sets of data were used viz raw and standardized data for estimation of genetic parameters. Lactation length heritability was 0.111±0.021 for standardized data and 0.053±0.018 for raw data using sire model. Low correlation was observed between raw data and standardized data for various production and reproduction traits, indicating that the findings in one data may not be true for the other. Based on the daughter's performance, breeding values of sires were also calculated and was used for ranking of sires. The study concluded that standardized data is recommended for estimating genetic parameters due to better results, however, raw data is believed to be more reliable for estimating breeding value and sire ranking because all aberrations are included without record editing.

Keywords: Murrah buffaloes, Lactation length, Risk factors, Genetic Parameters.

Signature of Major Advisor **Signature of Student**

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LIST OF ABBREVIATIONS

AB	:	Abortion
ANOVA	:	Analysis of Variance
AUC	:	Area under curve
BLUP	:	Best Linear Unbiased Prediction
EPLL	:	Extremely Prolong Lactation Length
ESLL	:	Extremely Short Lactation Length
GDP	:	Gross Domestic Product
GLM	:	Generalized Linear Model
LL	:	Lactation length
LS Mean	:	Least Squares Mean
PB	:	Premature Birth
PLL	:	Prolonged Lactation Length
REML	:	Restricted Maximum Likelihood
ROC	:	Receiver Operating Characteristic
SB	:	Still Birth
SD	:	Standard Deviation
SE	:	Standard Error
SLL	:	Short Lactation Length

CHAPTER – I

INTRODUCTION

India is the home tract of riverine buffaloes, and majority of the globally important buffalo breeds reside in the country (Sadana et al., 2005). It is also the foremost country in Asia to promote buffalo development, through application of scientific and technological interventions to improve their performances including genetic improvement (Borghese & Mazzi, 2005). Buffaloes are mainly utilized for their milk, meat and draught utility. The buffalo milk contains substantially more milk fat and SNF as compared to the cattle milk; and for this, buffaloes are preferred for various high fat or low moisture milk products. Due to their sturdiness, the buffalo males have been utilized extensively for agricultural draught power as bullocks. Furthermore, owing to various ethical and religious believes, prohibition of cattle slaughtering had continued since long throughout the country and this greatly increases the importance of buffaloes for meat production purpose as well. Also, there has been a high demand for buffen to be exported to Middle East countries.

Breeds of buffaloes have undergone selection for high milk production since long, specifically in the North-West region of India. Among them, Murrah is the most preferred breed of buffaloes by the Indian dairy farmers. The Murrah breed, being native of North India and having breeding tracts in Haryana and neighbouring states including Punjab, is one of the most promising breed of buffaloes on account of its milking capacity and promising genetic improvement. It had been utilized worldwide for genetic improvement of the native buffalo populations through crossbreeding/ upgrading and is the most widely present breed in the country (Breed survey, 2013) as well as in the world i.e., from Europe to South America and all over Asia, hence, given the name “black gold” (Sadana et al., 2005). Further, the efficient productivity and reproduction performance of Murrah buffaloes influence the success of Indian dairy industry (Jamuna et al., 2015).

In India, livestock sector alone contributes around 4.11 percent of the nation’s total Gross Domestic Product (GDP) at current prices during 2018-19, and amongst the livestock products, dairy sector leads the way. India produced over 198.4 million tonnes in 2019-20, accounting for about 20% of world milk production, thereby, occupying the global lead position (Economic survey, 2020-21). Buffaloes contribute approximately 49% of India's total milk production and subsequently acquire the highest contributor among dairy animals. Also in Punjab, per buffalo milk productivity is 8.44 kg as against 5.62 kg/day pan India, showing a better production potential among buffaloes in Punjab (BAHS, 2019). Aforementioned facts clearly depict the importance of buffaloes in India's agricultural economy, where GDP from milk has overtaken the GDP from any single grain.

Behind the accomplishments of dairy sector lies the importance of animals' production cycle. The dairy animal production cycle equals one calving interval which can be classified as lactation and dry period or in another way as service period and gestation. The period of time the animal produces milk in a single parity while excluding the initial five days of colostrum phase is designated as lactation length. Ten months of lactation length with a dry period of two months to get one year calving interval is usually considered as an ideal dairy production cycle for cattle. Howsoever in buffaloes, it is difficult to achieve in reality because of longer gestation period than cattle. A service period of two months is achievable to shorten the calving interval only in few buffaloes but the mean service period is usually higher than 60 days due to lack of proper management viz. oestrus detection and climatic stress mitigation and selection efforts focused mainly at milk production (Khan & Chaudhry, 2001). Though the ideal production cycle is difficult to achieve, globally, a length of 305 days has been accepted as the standard period of lactation for cattle and the same had also been adapted for buffaloes. So, any astounding deviation from the standard lactation length is considered to be abnormal i.e., lactations considerably longer than 305 days are prolonged lactations and shorter than the same are short lactations, the exact definition of which is yet to be standardized.

Being a dairy animal, lactation milk yield is the most important parameter of dairy buffalo (Chaudhry, 1992) and lactation length is one of the crucial factors affecting the amount of milk yield (Khan & Chaudhry, 2001). A strong linear correlation had been noted between lactation length and milk yield in buffalo (Khan 1997; Malhotra 2014). Longer the lactation length, higher is the milk production but it eventually leads to longer calving interval. Thus, breeding efficiency and milk production per day is adversely affected (Gahlot et al., 1993). Therefore, the adjoining effects of lactation length and amount of milk yield greatly influences the dairy sector.

In buffalo, short lactations are common (Tonhati et al., 2004) and in most literature, short lactation length are excluded from analysis considering that they are abnormal. So, this cut off point may result in loss of enormous data but including them can result in wide variation in the trait and conclusions made in the end can be quite different (Khan & Chaudhry, 2001). As a result of these, a criterion to decide, when to accept and discard certain lactations in breeding value estimations are still in question. Due to lack of information such as reasons or circumstances which leads to interruption of lactation is also a major obstacle in including short lactation length in genetic evaluations (Bajwa et al., 2002).

Factors which affect the lactation yield would also influence the lactation length in buffaloes (Chaudhry, 1992) and vice versa. Thus, the two important parameters in dairy animals viz milk yield and lactation length depend on both genetic and non-genetic factors. Genetic improvement till date, has been mostly brought about by selection based on milk yield in the dairy animals. The lactation length has extensively been used as one of the standardization criteria of data screening for genetic evaluation process, despite its large variability and the effect of this practice needs to be evaluated.

Lactation length accounts for a large proportion of the variations in milk production in buffaloes, as lactation milk yield increased with increasing lactation length (Bhat & Patro, 1978). Even though the importance of the lactation length has been known, there is still no consensus on procedures for handling it in genetic studies. The variability in lactation lengths is handled by three commonly found procedures firstly to adjust milk yield by the regression on lactation length phenotypically, next to exclude short lactations from the analysis by considering it ‘abnormal’ and lastly to use all records available, without either eliminating observations or adjusting yield on the basis of lactation length (Madalena, 1988). Invariably the longer lactation lengths are handled by trimming all lactation lengths at 305 days milk yield, this approach leads to discarding available data.

In observance of aforementioned facts and opinions, the present study was planned with the following objectives:

1. To identify incidences and risk factors for abnormal lactation length in Murrah buffaloes.
2. To estimate consequences of abnormal lactation lengths on performance of the Murrah buffaloes.
3. To evaluate impact of abnormal lactation lengths on genetic parameters.

CHAPTER – II

REVIEW OF LITERATURE

Lactation length among the dairy animals has always been a crucial trait, but it could not find its place for selection decision mostly due to its reportedly high genetic correlation with partial and complete milk yields. Longer lactations had been observed to increase the lactation milk yield but on the contrary, total lifetime milk produce will eventually be lesser compared to normal lactation of 305 days due to longer calving intervals (Afzal et al., 2007). Short lactation length on the other hand, has been identified as the most important risk factor for culling among Holstein cattle (Bell et al., 2010). Many genetic as well as environmental factors affect lactation length and many important traits in turn are affected by lactation lengths, a brief review of which has been organized below:

2.1 Variability of Lactation Lengths

A wide range of differences in the lactation length in Murrah buffaloes had been observed by different authors over the years, which are summarized and presented in Table 2.1.

Table 2.1: Variation of Lactation Length among Murrah buffaloes

Sr. no.	Mean±SE	Reference
1.	293.54±11.23	Rao and Kumari (2021)
2.	297.83±15.84	Verma et al. (2018)
3.	311.68±3.35	Jakhar et al. (2016)
4.	286.08±2.23	Jamuna et al. (2015)
5.	305.89±7.13	Pendor (2015)
6.	345.14±4.38	Raina (2015)
7.	306.76±65.39	Singh and Barwal (2012)
8.	312.80±5.70	Thiruvenkadan et al. (2010)
9.	313.19±2.77	Dass and Sadana (2000)
10.	335.00±5.10	Sethi and Khatkar (1997)
11.	265.67±13.88	Dhar (1993)

The average lactation lengths in Murrah buffaloes were ranging from 265.67 days (Dhar, 1993) to 345.14 days (Raina, 2015) which are clearly influenced by strategies of inclusion and trimming of lactation lengths apart from herd differences while a great deal of standard error as ±65.39 days, ensues in the study of Singh and Barwal (2012) as due to inclusion of all types of lactations in study. Baldi et al. (2011) studied the distribution of lactation lengths among 4408 lactations from Murrah buffaloes and found that out of all lactations, 86% had a complete lactation of 305 days, 70% of 270 and 11% of 150 days respectively. In the study carried out by Kumar et al. (2002), where average of first lactation length was 319.49±4.97, animals with incomplete or aberrant lactation records due to abortion or sickness were eliminated along with lactation length of fewer than 100 days. In the same farm under study, Malhotra (2014) reported a mean of 357.9±3.16 days for first lactation length. In his study, incomplete lactation records owing to stillbirth, premature birth, death, sale or transfer of animals during lactation were removed, as were data with lesser than 150 days of lactation or 1000 kg of milk yield.

2.2 Environment factors

The environmental factors include all the non-genetic factors that influence the phenotypic value of the animal both internal and external to the animals. The study of Behera et al. (2018) and Shivaji (2011) observed that when temperature-humidity-index (THI) was increased above comfort zone, there was a decline in milk yield and a negative significant association with milk yield and lactation length. This indicates how environment can have an impact on the production performance of the animals. Therefore, some major components under environmental factors which may affect the lactation length, as evidenced by the literature are as following:

2.2.1 Period of calving

The cumulative effect of gradual changes in the breeding, feeding, weeding and heeding practices over the years add over to significantly affect the performance of the animals within a farm. The effect of period is taken into consideration to evaluate and correct for such influences. The period of calving was reported to have highly significant effect on lactation length by Dass and Sadana (2000). Thiruvenkadan et al. (2010) and Malhotra (2014) accept these findings in Murrah buffaloes as well. El-bramony (2014) mentioned effect of period of calving as highly significant on lactation length in Egyptian buffaloes. Kumar et al. (2003) and Gupta et al. (2012) also reported that period of calving has significant effect on first lactation length. This variation may be attributed to differences in nutrition, rigorous culling of low performing animals and changes in genetic composition of herd owing to selection over the years and advanced husbandry practices to improve productivity of animals (Kumar et al., 2003). However, some studies such as Jamuna et al. (2015) may conclude it to be non-significant in Murrah buffaloes which may be attributed to either no significant changes over time or due to classification of periods with longer durations having large variation within the period itself.

2.2.2 Season of calving

Season of calving reflects the effect of meteorological parameters concurrent to the lactation of the animals. Season of calving had significant effect on lactation length of Murrah buffaloes studied by Dhar (1993). Dass and Sadana (2000) reported in Murrah buffaloes that the animals which calved during summer i.e., April-June showed longest lactation length with highest 305MY, stating that there is a significant effect on lactation length by season of calving. They concluded that the variation may be attributed to different managemental conditions due to feed and fodder availability and changing nutritional requirements of animals in different seasons.

Contrasting to the above study, the studies of Shivaji (2011) inferred that Murrah buffaloes calving in the month of September to November had the highest lactation length i.e., 310.65±2.25 days and produce more milk while the ones calved in summer showed average lactation length of 293.12±2.30 days. The same condition was evidenced by Hassan et al. (2017) where season of calving had a significant effect and longest lactation length was observed in winter calvers with an average of 245.83 days and the lowest was 207.49 days among summer calvers. Kumar et al. (2003) assented these findings in first lactation trait in which first lactation period was longest in winter calvers and shortest in summer calvers.

However, according to Chaudhry (1992), Afzal et al. (2007), the season of calving does not seem to have significant effect on lactation length in Nili Ravi buffaloes. Gupta et al. (2012), Malhotra (2014) and Raina (2015) agreed to these findings in Murrah buffaloes. Yadav et al. (2002) also reported that there were no significant differences in Murrah buffaloes for first lactation period. A non-significant effect was observed by Dhandapani et al. (2020) in Nili Ravi with a mean of 310.45±10.95 days in summer, 302.24±5.3 days for rainy season and 304.46±6.93 during winter season.

2.2.3 Parity

Dhar (1993) inferred that Murrah buffaloes that calved in 2nd and 8th parity had shorter lactation, indicating that parity has a significant effect on lactation length. Hassan et al. (2017) concurred to this finding, where in his studies, parity had significant effect on lactation length though the result was different as buffaloes of 4th parity had longer lactation length as compared to those in 2nd and 6th according to his work. Chaudhry (1992) reported that parity had significant effect on lactation length in Nili Ravi with maximum at 1st and minimum in 6th parity and Khan and Chaudhry (2000) also mentioned that younger buffaloes had longer lactation length. Research conducted by Dhandapani et al. (2020) on Nili-Ravi further reported that parity had significant effect on lactation length, indicating that 1st parity had longest lactation days accompanied with a high standard error (324.28±98 days) while shortest length was seen in 3rd and above parities. In contrast to these, Jamuna et al. (2015) in Murrah breed and Afzal et al. (2007) on Nili Ravi found no significant effect by parity on lactation duration. Similarly, Habib et al. (2010) and Nawaria et al. (2015) found it to be insignificant in Red Chittagong cattle and Sahiwal respectively.

2.2.5 Gender of the Calf

In Nili Ravi, (Chaudhry, 1992) observed an average lactation period of 305.72±2.67 days on the animals giving birth to male calves while in female calvers, 297.84±2.51 days was seen. The differences were found to be significant, thus, concluding that the gender of calf born have significant effect on lactation length whereas Afzal et al. (2007) reported it to be non- significant.

2.2.6 Background of Animal

According to Dass and Sadana (2000), location of the farm had high significant effects on lactation length when they compare two different farms. They suggested that between farms variation might be due to accumulation of differences in climatic conditions and managemental practices. Kumar et al. (2003) and Yadav et al. (2007) also reported that farm had significant influenced on first lactation period in Murrah. Chaudhry (1992) outlined that among Nili-Ravi breed, lactation length of purchased animals were shorter (287.74±4.03 days) in comparison to organised farm born (305.34±38.04 days). However, Tewari et al. (2020) opposed to these findings in first lactation period in buffaloes.

2.2.7 Incidence of diseases

Lameness is one of the most prevalent cases of dairy animals which can affect the performances of animals. Thus, Kshandakar et al. (2017) highlighted the effect of lameness in Murrah buffaloes where lame animals had shorter lactation period (236.72±12.85 days) compared to healthy ones (278.59±2.66 days). Tranter and Morris (1991) derived that 26% of the loss was associated with lactation shortening in cows with lameness, where average lactation days were 12 days shorter and pre-mature culling had to be done because of low production and reproductive performances.

Another important and common disease for dairy industry is mastitis. The losses caused by it are not only economical but also affect milk quality, antibiotic resistance and overall animal health. Jingar et al. (2014) while studying Murrah breed confirmed that buffaloes have more resistance to mastitis compared to cows and number of parities also influenced the incidences. They reported an increased in mastitis incidences from 22 to 32% as parity number increases.

In accordance to the study by Khan and Chaudhry (2001), for animals having lactation length lesser than 308 days, reasons of early onset of dry period were known for 25% out of which 31% suffered from mastitis, 13% were reported of having bad temperament, 40% were because of reproductive problems and other reasons such as still birth, old age, disease etc. and 16% were auctioned while animals were in milk and thus, were reported as short lactation Moreover, among animals having lactation length shorter than 8 weeks, incidences of mastitis and reproductive problems were most common.

Philipsson (1976) excluded all lactations shorter than 46 days in milk and reported a higher proportion of such short lactations in cows with dystocia or stillbirth. Khan and Chaudhry (2001) reported abrupt short lactations in Nili Ravi buffaloes during their studies out of which 31% had mastitis, 40% due to reproductive problems, disease etc. Silvia (2003) wrote that poor reproductive performance and decline in fertility also result in longer lactations. These eventually leads to an increase in culling rate because of reproductive reasons.

2.3 Genetic Parameters

2.3.1 Effect of Sire

Tewari et al. (2020) found that sire influenced both the dam's and daughter's record on first lactation length in Murrah buffaloes. The same was observed by Chaudhry (1992) in Nili Ravi buffaloes where significant differences were observed for daughters of different bull.

2.3.2 Heritability

Heritability can be defined as the phenotypic differences attributable to genetic variation. Estimation made by Dhar (1993), Thiruvenkadan (2010), Malhado et al. (2013), Malhotra (2014) and Jakhar et al. (2016) were 0.15±0.001, 0.01±0.08, 0.15±0.03, 0.12±0.09 and 0.357±0.095 respectively for Murrah buffaloes. In crossbred Murrah, Barros et al. (2016) found a low heritability of 0.09±0.01 and made a conclusion that lactation length is mainly influenced by non-genetic factors.

The studies conducted on first lactation traits by Dass and Sadana (2000) and Kumar et al. (2002) on Murrah buffaloes also stated that lactation length have low heritability on the herd they studied. A value of 0.05±0.13 was reported by Dass and Sadana (2000) and Kumar et al. (2002) estimated it to be 0.07±0.17 whereas Yadav et al. (2002) calculated to be 0.94±0.15.

In Nili-Ravi, Khan (1997) estimated the heritability for lactation length to be low as 0.06 while Galsar et al. (2016) reported a bit higher value as 0.17 and claimed that it is low and non-significant in Mehsana buffaloes. Lactation length heritability in Brazil buffaloes obtained by Garcia et al. (2013) was 0.13±0.06 and in Egyptian buffaloes for first lactation length by EL-Bramony (2014) was 0.11.

2.3.3 Repeatability

Repeatability is the ability of animal to repeat its performance over repeated production cycles. The repeatability of lactation length was found to be 0.25±0.03 by Dhar (1993) and 0.16 by Malhado et al. (2013) in Murrah. Khan (1997) estimated to be moderately low i.e., 0.16 in Nili-Ravi and Khan and Chaudhry (2001) reported it to be 25% repeatable while Galsar et al. (2016) mentioned that repeatability for lactation length was low but highly significant with a value of 0.12 in Mehsana. Bajwa et al. (2004) also estimated the repeatability to be 0.326±0.025 (P<0.01) in Sahiwal cattle.

2.3.4 Correlation of lactation length with other traits

Correlation shows the extent to which one variable can vary in accordance to another variable. Genetic correlation measures the degree of association between the breeding values for respective traits and phenotypic correlation is a measure of degree of association between phenotypic values for the traits among the individuals.

a) Milk yield

Several scientists described the genetic correlation of lactation length with other economically important traits. Malhado et al. (2013) found the correlation between milk yield and lactation length to be significant, positive and moderate i.e., 0.48 in Murrah buffaloes, Garcia et al. (2013) estimated it to be 0.63 in Brazilian buffaloes and Khan (1997) found as 0.70 in Nili Ravi buffaloes. The genetic correlation of lactation length in Murrah for the present herd was reported to be 0.94±0.16 with lactation milk yield but the same was not significant with 305 days milk yield (Malhotra, 2014).

The study on production traits of Murrah buffaloes by Jakhar et al. (2016) revealed that total milk yield and 305 days milk yield have high positive genetic and phenotypic correlation (P≤0.01) i.e., 0.722±0.686 and 0.482±0.376. Barros et al. (2016) also reported that milk yield and lactation length have high and positive genetic correlation, further stating that direct selection to improve milk yield will also increase lactation length.

Yadav et al. (2002) found a positive significant (P<0.01) phenotypic and genetic correlation of first lactation milk yield with lactation period as 0.54±0.03;0.543±0.11, respectively in Murrah buffaloes, depicting the higher first lactation yield was associated with longer lactation periods. The findings of similar implications were also reported by Singh and Barwal (2012).

Afzal et al. (2007), in their studies on Nili-Ravi estimated a positive correlation of lactation length with milk production (0.623, P<0.05). Lowest milk yield was seen in lactations shorter than 240 days and highest among lactations of more than 361 days (P<0.05). El-bramony (2014) found that first lactation milk yield has moderate but positive genetic correlation with first lactation length in Brazilian buffaloes. In terms of persistency of milk yield, Das et al. (2007) reported negative and low correlation with first lactation length (-0.122±0.086) in Swamp buffaloes. Khan and Chaudhry (2000) regressed lactation length on milk yield as 0.062±0.0015 days and suggested that for every 100 kg increase in milk yield, lactation length will increase by 6.2 days.

b) Peak yield

A high positive genetic correlation of 0.151±0.041 and phenotypic correlation of 0.107±0.27 ($P<0.05$) between peak yield and lactation length were observed in Murrah by Jakhar et al. (2016) whereas in Mehsana, Galsar et al. (2016) found a negative and non-significant correlation of lactation length with peak yield. A phenotypic correlation of -0.16±0.25 and genetic correlation of -0.14±0.04 were seen.

c) Service period

Service period remarkably had positive correlation with lactation length depending on their age at first calving studied by Verma et al. (2018). This may be due to anti-gonadotropic effect of prolactin and negative energy balance on high yielding animals. Jakhar et al. (2016) estimated a genetic correlation of 0.748±0.08 with phenotypic correlation of 0.587±0.47 ($p<0.01$) in Murrah.

d) Dry period

Jakhar et al. (2016) reported a value of 0.137±0.112 for genetic correlation and 0.258±0.172 for phenotypic correlation between dry period and lactation length. Singh and Barwal (2012) also found a positive genetic and phenotypic correlation of first lactation period with first dry period i.e., 0.183 and 0.563

e) Calving interval

Calving interval was seen to have high correlation with lactation length according to Verma et al. (2017) meaning that longer the lactation length, longer is the calving interval. The reason could be due to the negative energy balance imposed by lactation which impaired the reproductive cycle. Jakhar et al. (2016) further reported a positive correlation wherein the genetic and phenotypic correlation with lactation length were 0.779±0.075 and 0.660±0.583 ($P<0.01$) respectively. Barros et al. (2016) also found positive genetic as well as phenotypic correlation between calving interval and lactation length (0.1,0.75).

2.4 Incidences of Abnormal Lactations

Baldi et al. (2011) reported that 86%, 70% and 11% out of complete lactations had a length equal to or lower than 305, 270 and 150 days, respectively among Brazilian buffaloes. In the study of Afzal et al. (2007), out of 508 lactation records, 16.14% were lesser than 181 days. Truncation was done for records lesser than 181 days and more than 448 days. Analysis results showed that 10.79% fell in the range of 182-210 days while 6.8% were in the range of 361 to 447 days. Khan and Chaudhry (2001) had mentioned that shorter lactations were more likely to be considered as atypical than longer lactations. In their findings, they reported that 59.2% out of 2704 lactations had lactation period shorter than 44 weeks. Moreover, Anil et al. (2016) had considered any culling of animals during their lactations, whichever the reason may be, as abnormal.

Chaudhry (1997) considered a range of 181 to 300 days of lactation as normal in his studies on Nili Ravi but found that 48% animals had a lactation length more than 300 days. In dairy cattle studied by Vaccaro et al. (1999) approximately 240 days of lactations and above were considered to be normal but 21% of the records they studied fell outside the normal category while on the other hand, Canaza-Cayo (2016) observed 2.5% lactation periods shorter than 100 days in his study.

2.5 Truncation of data

The lack of information on the reasons or circumstances leading to the interruption of lactation is the major obstacle in including short lactation length records in genetic evaluations (Bajwa et al., 2002). Madalena (1988) concluded in his research on tropical cattle that if exclusion of short lactation records is done, reduction in selection accuracy of both progeny test and genetic variation in milk yield should be expected. Khan (1997) found that when lactation length was truncated between 180 to 305 days in water buffaloes, the coefficient of variation was reduced. Further, Baldi *et al*. (2011), Khan and Chaudhary (2000) indicated an increase in heritability estimates when total milk yield was adjusted for days in milk in buffaloes indicating an inflated additive genetic variance estimate. Baldi et al. (2011) obtained highest additive genetic variances with multiplicative correction factors and the lowest when ‘days in milk’ was included as a covariable in the model for adjustment of short lactation in Brazilian buffaloes. They further concluded that reliable breeding value can be estimated when short lactations were included in the analysis and by adjusting milk yield for days in milk.

When Bajwa et al. (2004) estimated the lactation length in Sahiwal, they obtained an average of 289 days when no restriction was given for maximum values but when data was truncated at 308 days, average declined to 247.7±66 days. Canaza-cayo (2016) also observed a decline of 7-9% in additive genetic and residual variances for milk yield when short lactations were excluded regardless of their genetic group.

CHAPTER – III

MATERIALS AND METHODS

3.1 Sources of Data

The data for the present research were collected from the registers maintained at the Directorate of Livestock Farm of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana from the period of 2005 to 2020 accounting for a total of 16 years. The relevant information for the present investigation i.e., production, reproduction, pedigree, and disease incidences were compiled from the calving registers, dry cow registers, calving registers, production registers, reproductive registers, and treatment registers and complied thereafter.

Two sets of data were used for a comparative study of inclusion and exclusion of abnormal lactations; where one set comprises of all the data without exclusion of any type of lactation lengths in buffaloes. In the second set, the animals with abnormal lactation lengths were excluded from the study. Only records of animals completing their lactations during the herd life were taken into account for the study.

3.2 Management of the herd

The herd of the animals under study was kept in groups in a loose housing system with a partly covered shelter area at the Directorate of Livestock Farms. Separate housing was provisioned for calves, heifers, milking, dry, advanced pregnant females and breeding bulls. The animals had free access to feed and water while the total mixed ration (TMR) containing a blend of greens, dry fodder, concentrate, mineral mixture, and other feed additives formulated depending on the stage of the animals were provided. Milk yield was recorded daily as and when milking was done separately for each animal. Reproduction was carried out via artificial insemination. Most of the important events were recorded in their respective registers with pertinent details.

3.3 Classification of data

The data recorded were categorized into different subgroups for both internal and external factors that may affect the performances of the animals and thus require to be corrected for them. Such inclusion with classification is done to achieve better predictability, error minimization, and ease of analysis. The external factors that may influence animal’s performance includes seasonal variations considered as the month of calving, management, and other changes over the years accounted in and as the period of calving, and internal factors consist of parity and disease incidences. The scheme of classification of the livestock data considered in the present study is described as under:

3.3.1 Month of calving

The month of calving had been included in several studies as an indicator of seasonal variations and was found to be significant (Ahmad et al., 1981; Barash et al., 2001; Genc & Mendes, 2021). Thus, as the duration and starting of different seasons changes every year and the ideal classification of months into seasons is difficult, calving incidences were taken as twelve months of calving from January to December in the present study.

3.3.2 Period of Calving

The sixteen years of total duration under study i.e., 2005 to 2020 were divided into four periods based on year of calving with four years interval as shown in table 3.1.

Table 3.1: Classification of periods for the study

S. No.	Period Code	Year of calving
1.	P1	2005-2008
2.	P2	2009-2012
3.	P3	2013-2016
4.	P4	2017-2020

3.3.3 Parity

The animals those completing at least one lactation during their herd life were included in the analysis and the parities were classified in accordance to the convention described in table 3.2.

Table 3.2: Classification of the parities of the animals

S. No.	Parity group	Parities included
1.	Pa1	First
2.	Pa2	Second
3.	Pa3	Third-fourth
4.	Pa4	>Fifth

3.3.4 Lactation length

The lactation lengths for individual parities of different animals were divided into five groups using the variability in the lactation length around its' mean as indicated by standard deviation units, as described in table 3.3.

Table 3.3: **Classification of the lactation length categories**

S. No.	Lactation category	Lactation length (days)
1.	Extremely short lactation (ESL)	Up to Mean LL-1.5SD
2.	Short lactation (SL)	Mean LL -1.5SD to Mean LL -1SD
3.	Normal lactation (NL)	Mean ± 1SD
4.	Prolonged lactation (PL)	Mean + 1SD to Mean + 1.5SD
5.	Extremely prolonged lactation (EPL)	More than Mean +1.5SD

3.3.5 Incidence of disease

Any disease conditions, which occurred from the time of calving, until the animal dried off, were analysed and recording of the disease incidences was done by a dichotomous method where the presence of disease was marked as '1' and absent was marked as '0'. Duration of the disease per lactation and incidences per lactation day was also recorded.

Incidence of disease (I) = 0 OR 1

3.4 Standardization and normalization of data

To prepare a routine breeding analysis data from the raw data, standardization and normalization was performed using the following guidelines:

- Animals that had completed at least one lactation were included in the study.
- Animals having incomplete/abnormal lactation due to reasons such as abortion, premature birth, stillbirth, sickness, culling, or death during the lactation period were excluded from the study.
- Experimental animals were not included in the study.
- Animals with short and extremely short lactation lengths were excluded
- The values that lie within the range of Mean ± 2.54 standard deviations (99% coverage) were included under the analysis, whereas, the values that lie outside the range (outliers) were excluded.

3.5 Statistical Analysis

The data were analysed by using standard procedures in the SAS software version 9.3 (SAS Institute, Cary NC, USA) and BLUPF90 family of software (Misztal et al., 2018).

3.5.1 Risk factor Analysis

The data for risk factor assessment were analysed by performing logistic regression (Proc Logistic) and lactation lengths were analysed using mixed model analysis (Proc Mixed) in the SAS software version 9.3. Logistic regression is a method of statistical analysis used for modelling dichotomous outcome variables, though it tells the probability, it is usually used for classification. In this study, logistic regression was done to know the effect of various factors on lactation length and classify it according to significant and non-significant. For mixed model analysis, the restricted maximum likelihood (REML) method was deployed as an estimation method with sire and animal nested within sire as random effects. This was done to estimate the quantitative effect of risk factors on lactation length variation. The non-significant effects found were eliminated one by one starting from the variable with the highest p-value. This procedure was repeated with continuous elimination of factors, which has the highest p-value in each preceding step until all the retained effects in the model achieved significance (p≤0.05). This was done to resemble the procedure of backward elimination selection. The statistical model used are as follows:

Statistical model for logistic regression:

$$\boldsymbol{Y_{ijklmnopu} = X_{ij} + P_k + M_l + Pa_m + R_{no} + C_p + e_{ijklmnopu}}$$

Where,

$Y_{ijklmnopu}$ = observation of u^th animal

X_{ij} = regression of j^th incidence of i^th disease

P_k = effect of k^th period of calving on u^th animal

M_l = effect of ;^th month of calving on u^th animal

Pa_m = effect of m^th parity on u^th animal

R_{no} = effect of o^th incidence of n^th type of reproductive problem

C_p = effect of p^th type of calving

$e_{ijklmnopu}$ = residual term, NID ~ $(0, \sigma^2_e)$

Statistical model for mixed model analysis:

$$Y_{ijklmnopru} = \sum b_i X_i + P_j + MC_k + Pa_l + R_{no} + D_{pr} + S_t + A_u(S_t) \ldots + e_{ijklmnopru}$$

Where,

$Y_{ijklmnopru}$	= observation of uth animal
$\sum b_i X_i$	= regression of incidence of disease
P_j	= effect of jth period of calving on uth animal
MC_k	= effect of kth month of calving on uth animal
Pa_l	= effect of lth parity on uth animal
R_{no}	= effect of oth incidence of nthtype of reproductive problem
D_{pr}	= effect of rth incidence of pth disease
S_t	= random effect tth sire
$A_u(S_t)$	= random effect of uth animal nested within tth sire
$e_{ijklmnopru}$	= residual term, NID ~ (0, σ^2_e)

3.5.2 Comparison of parameters

The production parameters i.e., lactation length, service period, dry period, calving interval, gestation period, days to reach peak yield, peak yield, 305 days milk yield, lactation milk yield, average fat percentage, were analysed in between different classes of lactation length using general linear models (Proc GLM) and Post Hoc comparison of the Least Squares Means.

The genetic parameters viz. heritability and genetic correlation were estimated from the two sets of the data as follows:

- The data trimmed of the abnormal lactation lengths
- The data inclusive of the abnormal lactation lengths

3.5.3 Estimation of heritability

The heritability of the traits was estimated from variance components estimated through the REML method in the BLUPF90 family of software (Misztal et al. 2018) as follows:

$$h^2 = 4t = \frac{4\sigma_s^2}{\sigma_s^2 + \sigma_w^2}$$

Where,

t	=	intra-sire correlation among paternal half sibs
σ_s^2	=	between sire component of variance
σ_w^2	=	within sire component of variance
h^2	=	heritability

3.5.4 Estimation of genetic correlation

The genetic correlations of the traits were estimated from covariance and variance components estimated through REML method in BLUPF90 family of software (Misztal et al. 2018) as follows:

$$\mathrm{r}_{\mathrm{g}_{\mathrm{xy}}} = \frac{\mathrm{Cov}_{\mathrm{s}_{\mathrm{xy}}}}{\sqrt{\sigma^2_{\mathrm{s}_\mathrm{x}} \times \sigma^2_{\mathrm{s}_\mathrm{y}}}}$$

Where,

X, *Y*	= different traits
$Cov_{s(XY)}$	= sire component of covariance between traits X and Y
$\sigma_s^2{}_{(X)}$, $\sigma_s^2{}_{(Y)}$	= sire component of variance for trait X and Y respectively.

3.5.5 Estimation of sire rank correlation

The breeding values of the traits were estimated with the best linear unbiased prediction (BLUP) method using the variance-covariance components estimated through REML in the BLUPF90 family of software (Misztal et al., 2018). The estimated breeding values from both the data were utilized here onwards in SAS version 9.3 to calculate the Spearman Rank correlation between the breeding values for different datasets for the same trait to confirm the extent of similar sire ranks in the two data sets. The formula used was as follows:

$$\boldsymbol{r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)}}$$

Where,

d_i	= difference in the sire ranks for two data sets
n	= numbers of pair of observations
r_s	= Sire rank correlation

CHAPTER – IV

RESULTS AND DISCUSSION

The present study was conducted with the above-mentioned objectives to evaluate the abnormal lactation length in Murrah buffaloes. Lactations between 2015 and 2020 were recorded along with the incidences and risk factors that can influence the lactation length. The lactation length was divided into 5 categories i.e., normal, short, extremely short, prolong and extremely prolong and any lactations outside the normal category were considered abnormal. The factors correlating to the abnormal lactation length were determined using logistic regression and mixed model analysis in SAS software version 9.3 to discern whether they have any significant effect or not. Furthermore, to know the consequences of abnormal lactation length on various important economic traits, General linear model (GLM) was used in the same software. The genetic parameters were estimated using REML and breeding values of sires were estimated with sire model (BLUP) in BLUPF90 family of software, paving the way for a better selection method in the herd.

4.1 Data structure

The data of 1235 lactation records of 470 animals maintained at Directorate of Livestock Farm, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) were analysed for 2005 to 2020 period. A brief summary of the data used in the study is given in table 4.1 and descriptive statistics for various production and reproduction traits are shown in table 4.2.

Table 4.1: Summary of data structure in Murrah buffaloes

Data	Number
Sires	164
Animals	470
Lactations	1235
Duration	2005-2020

Table: 4.2: Descriptive statistics for various production and reproduction traits

Variable	N	Mean±S.E	Median	Standard Deviation	Skewness	Kurtosis	CV (%)	Range
Lactation length (days)	1235	295.886±3.420	299	120.21	-0.095	1.667	40.627	987
Lactation milk yield (kg)	1235	2229.604±28.785	2277.3	1000.056	0.202	1.039	44.854	7084.5
305 days milk yield (kg)	1235	2060.268±23.639	2171.1	821.298	-0.375	0.599	39.864	5639.8
Peak yield (kg)	1194	12.53± 0.100	12.5	3.484	0.013	1.544	27.805	25.6
Days to reach peak yield (days)	1189	47.344±1.055	41	36.387	4.997	46.385	76.857	464
Average fat percentage	929	7.722±0.067	7.6	2.071	14.847	246.976	26.819	39.6
Service period (days)	979	171.446±4.273	124	133.706	2.067	6.208	77.987	918
Dry period (days)	837	160.211±4.3	127	124.422	3.988	28.534	77.661	1606

The average lactation length for Murrah buffaloes was found to be 295.886±3.420 days which is in accordance to lactation length estimated by Rao and Kumari (2021) and Verma et al. (2018) i.e., 293.54±11.23 days and 297.83±15.84 days respectively and was also in close proximity to the lactation length reported by Pendor (2015) which was 305.89±7.13 days. On the other hand, for the current farm under study, Malhotra (2014) observed a mean of 357.9±3.16 days for first lactation length and Raina (2015) reported 345.14±4.38 days after standardization of data. The discrepancies in performance could be attributable to varied time intervals, standardisation methods and the number of observations they analysed which ranged from 1992 to 2012, and the number of animals studied was 1033 by Malhotra (2014) and 1935 by Raina (2015) respectively. Furthermore, as lactation length has a low heritability, it is apparent that non-genetic factors have a large influence on it, and as the years progress, the likelihood of non-genetic factors to change is considerable.

The mean of total lactation milk yield without any adjustment was 2229.604±28.785 kg which is similar to the finding of Pawar et al. (2012) i.e., 2229.8±93.7kg for the same breed. Malhotra (2014) estimated the average first lactation milk yield as 2118.9±26.67kg for the same herd at a previous time. The majority of other findings reported a lower milk yield such as 1723.71±77.64kg by Rao and Kumar (2021), 1877.29±45.59 kg by Pendor (2015), 1865±10.83kg by Narayan (2011), and 1686.2±44.4kg by Thiruvenkadan et al. (2010) in Murrah buffaloes.

The average 305-day milk yield was 2060.268±23.639 kg. A mean of 879.4±18.85 kg had been reported by Malhotra (2014) for the first 305-day milk yield for the current farm. Jakhar et al. (2016) also found an average 305-day milk yield of 2060.93±20.22 kg and Jamuna et al. (2015) reported an average of 2078.20±31.21 kg in Murrah buffaloes. Pawar et al. (2012) estimated a higher yield of 2147.6±87.06 kg whereas; Thiruvenkadan et al. (2010) reported a lower milk yield average of 1616.3±39.6 kg.

In the present study, the mean peak yield was found to be 12.53±0.1 kg which is similar to Das and Sadana (2000) finding i.e., 12.04±0.14 kg. The average peak yield for the first lactation was 10.46±0.07 for the same farm according to Malhotra (2014). On the other hand, other studies reported a lower yield of 10.69±0.46 kg by

Rao and Kumari (2021), 10.08±0.96 kg by Jakhar et al. (2016), 6.05±0.15kg by Pendor (2015), and 8.45±0.6 kg by Narayan (2011).

The average days to reach peak yield was 47.344±1.055 days in the present herd which is in close agreement with the finding of Malhotra (2014) i.e., 50.7±1. Pendor (2015) and Narayan (2011) also reported similar days to reach peak yield which were 44.51±1.89 days and 42.52±0.25 days respectively.

The mean 'average fat percent' was 7.722±0.067% whereas Malhotra (2014) found 7.13±0.03% for first lactation yield. The present finding is much higher compared to other studies like the finding of Narayan where the mean of average fat percentage was 7.17±0.14% and Pawar et al. (2012) which was 7.12±0.11%.

The mean service period was 171.446±4.273 days which is comparable to Rao and Kumari (2021) finding as 164.13±20.3 days and closely related with the studies of Jakhar et al. (2016) which was 187.10±5.91 days. However, Jamuna et al. (2016) reported a shorter service period of 139.91±2.96 days while Pendor (2012) and Thiruvenkadan et al. (2010) found a much longer period i.e., 205.35±7.03 and 253.7±17.3 days.

The average dry period was estimated as 160.211±4.3days. A similar result was reported by Narayan (2011) i.e., a dry period of 161±0.3 days in his study on Murrah buffaloes while Rao and Kumari (2021), Jakhar et al. (2016), and Das and Sadana (2000) found a longer period of 173.8±27.03, 173.34±5.59 and 172.84±5.5 days respectively.

4.2 Classification of data

4.2.1 Lactation length

Table 4.3 shows the lactation length distribution according to the standard deviation (SD) units. From this table, it is evident that 76.19% of the recorded data fall in the normal category i.e., between -1SD to +1S.D units from the mean LL. Short lactation length was estimated to be around 5.26% of the total lactations studied while extremely short lactation comprises 6.40% that were less than mean LL-2SD. Out of 1235 lactation records, 7.29% was found as prolonged lactation, lying in the range of Meal LL +1SD to +1.5S.D and 4.86% as extremely prolonged lactation that went beyond mean LL+2 S.D. The lactation length (LL) recorded was categorized into 5 classes according to their dispersion from the mean as shown in table 4.4. Lactation period lesser than 116 days was considered extremely short while lactation length between 116 and 176 days was regarded as short lactation. A wide range of days i.e., 177 to 416 was considered as normal lactation length. Lactation length between 417 and 477 was classified as prolonged lactation whereas lactation length falling beyond 477 was termed as extremely prolonged lactation.

Table 4.3: Dispersion of lactation length in standard deviation units from mean

Lactation length		Frequency	Percentage	Cumulative percentage	
Scatter from Mean	Days			Less than type (%)	More than type (%)
< -2 S.D	< 56	41	3.32	3.32	100
-2 S.D to -1.5 S.D	56-116	38	3.08	6.40	96.68
-1.5 S.D to -1 S.D	116-176	65	5.26	11.66	93.60
-1 S.D to -0.5 S.D	176-236	112	9.07	20.73	88.34
-0.5 S.D to 0.5 S.D	236-356	648	52.47	73.20	79.27
0.5 S.D to 1 S.D	356-416	181	14.66	87.85	26.80
1 S.D to 1.5 S.D	416-477	90	7.29	95.14	12.14
1.5 S.D to 2 S.D	477-537	35	2.83	97.98	4.85
>2 S.D	> 537	25	2.02	100	2.02

Table 4.4: Final classification of lactation length in Murrah buffaloes

S. No.	Category	Range (days)	Lactation records (N)	Percentage (%)
1.	Extremely short lactation	<116	79	6.40
2.	Short lactation	116-176	65	5.26
3.	Normal	177-416	941	76.19
4.	Prolong lactation	417-477	90	7.29
5.	Extremely prolong lactation	>477	60	4.86
	Total		**1235**	**100**

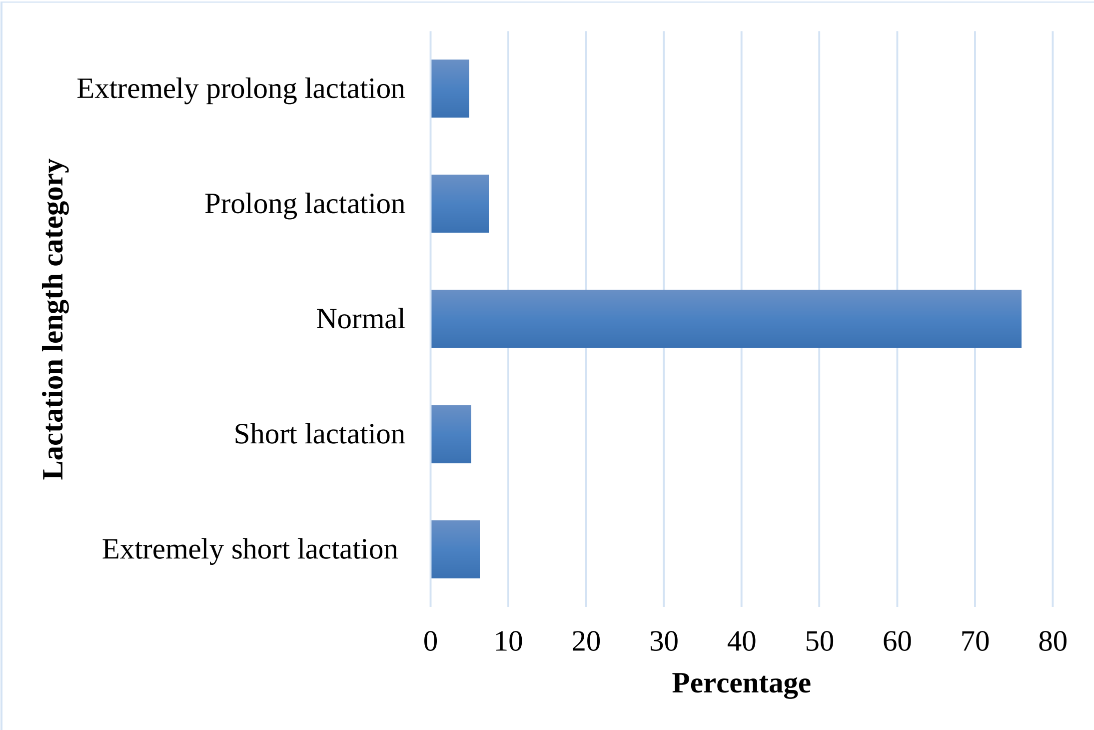

Fig. 4.1: Distribution of lactation length categories in Murrah buffaloes (in percentage)

4.2.2 Parity

Frequencies of different lactation length category for different parity group had been classified in table 4.5. First parity group had the highest incidences of prolonged lactation length. From table 4.5, it is evident that as animals aged and the number of parity increases, the chances of having short lactation also increases. The same result was also found by Dhandapani et al. (2020) and Chaudhry (1992) indicating that 1st parity had the longest lactation period.

Table 4.5: Lactation length distribution for different parity in Murrah buffaloes

Category	Parity 1	Parity 2	Parity 3	Parity 4	Total
Extremely short lactation	17	16	27	19	79
Short lactation	15	10	19	21	65
Normal lactation	271	241	264	165	941
Prolonged lactation	39	23	19	9	90
Extremely prolonged lactation	29	14	10	7	60
Total	371	304	339	221	1235

4.2.3 Repeated abnormal lactation incidences

Out of the total animals studied, the percentage of animals having repeated abnormal lactation length during their lifetime production cycle is of crucial importance (Table 4.6). Among the different lactation categories, prolonged lactation had the highest number of animals indicating that it had the greatest chance to occur more than once in the lifetime production of animals or in other words, animals showing prolonged lactations are likely to retain their performance in the subsequent cycle followed by extremely prolonged i.e., 2.26% and 0.80% out of 1235 lactation records.

Table 4.6: Summary of animals having repeated abnormal lactation lengths

Category	Percentage of animals
Extremely short lactation	0.08
Short lactation	1.53
Prolonged lactation	2.26
Extremely prolonged lactation	0.80
Total percentage of animals	4.67

4.2.4 Type of calving

Calving of animals had been categorised into 4 types according to the survivability of the foetus at the time of birth or during the gestation period and mean gestation length and standard deviation (Table 4.7). The mean gestation period in the study including all types of calving was observed to be 304.802±0.820 days while the standard deviation was observed as 29.326 days. The gestation period of 276 days (Mean gestation period -1SD, raised to the next integer value) was taken as a point of classification upon which calving occurring before or after it was considered as pre-term, and occurring after it as full term.

Table 4.7: Classification of gestation period

S. No.	Gestation period	Calf survival	Calving type	Frequency	Percent
1.	<276 days	Dead	Abortion	43	3.48%
2.	<276 days	Live	Premature birth	7	0.57%
3.	≥276 days	Dead	Stillbirth	25	2.02%
4.	≥276 days	Live	Normal	1160	93.92%

Premature birth was considered as a calf born before 276 days and lived, whereas abortion was defined as a calf born dead before 276 days of gestation period. If the dead calf was born after 276 days of gestation, it was deemed as stillbirth; however, if the calf survived, it was regarded as normal birth.

4.3 Disease incidence and duration

The disease or any condition having the possibility of being a risk factor for deviation of lactation length had been classified in table 4.8. The incidences were categorised broadly into infection and infestation, udder ailments and injuries, locomotion injuries, reproductive complications and injuries, and unclassified conditions. The duration for reproductive conditions that cannot be repeated during a particular lactation cycle such as abortion, stillbirth, premature birth, dystocia, retention of placenta, repeat breeding, and other diseases like foot and mouth disease was taken as one during the analysis. For other diseases which can occur repetitively during one lactation cycle, the frequency of occurrence during one lactation cycle along with their duration was recorded. Moreover, incidences per lactation day were also calculated by dividing the duration of disease by lactation length. The incidence per lactation day denotes the chances of animals having a particular disease/condition during one lactation cycle.

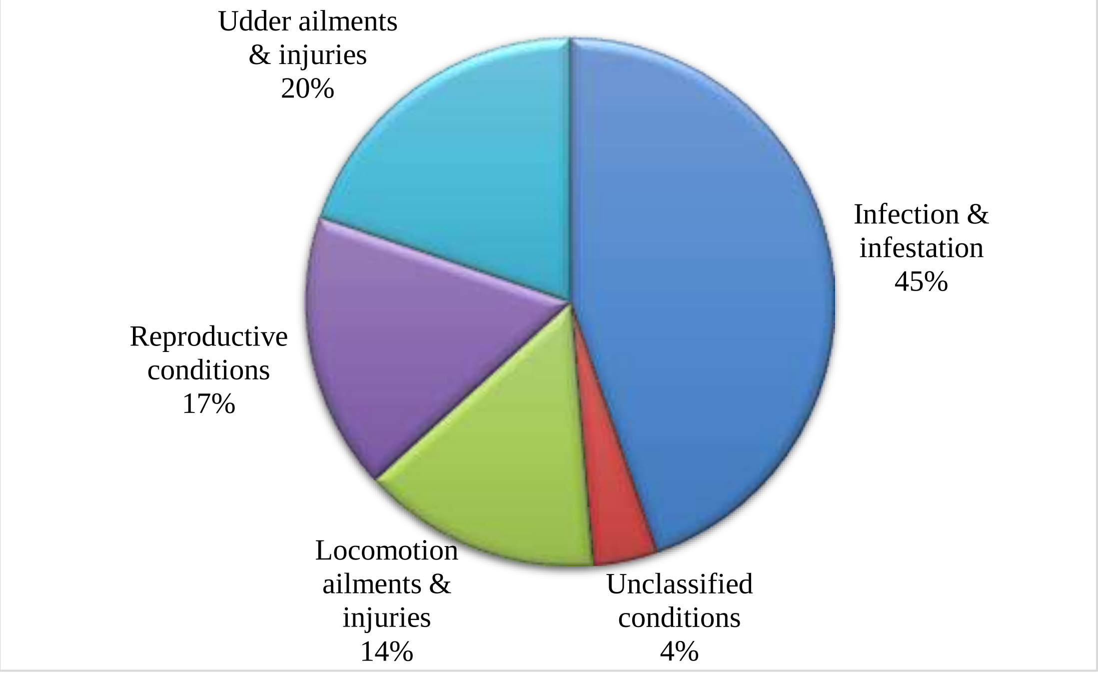

Figure 4.2: Proportions of Incidences of diseases and other conditions in the Murrah animal

Table 4.8: Descriptive table for disease incidences during the lactation period

Category	Disease/condition	Frequency	Frequency (%)	Duration
Infection & infestation	Pyrexia	944	42.70	1274
	Foot and mouth disease	7	0.32	124
	Diarrhoea	20	0.90	73
	Abscess	16	0.72	205
Udder ailments & injuries	Udder swelling	12	0.54	81
	Udder wound	218	9.86	2633
	Mastitis	207	9.36	1283
Locomotion ailments & injuries	Leg wound	166	7.51	2503
	Lameness	156	7.06	1096
Reproductive conditions	Prolapse	38	1.72	195
	Metritis	3	0.14	42
	Vulva wound	17	0.77	213
	Pyometra	2	0.09	5
	Torsion	1	0.05	---
	Abortion	43	1.94	---
	Pre- mature birth	7	0.32	---
	Stillbirth	25	1.13	---
	Repeat breeding	150	6.78	---
	Dystocia	7	0.32	---
	Retention of placenta	85	3.84	---
	Off fed	19	0.86	70
	Weakness	20	0.90	226
	Rare condition/other diseases	48	2.17	257
	Total	2211		

4.4 Risk factor analysis using logistic regression with backward elimination

4.4.1 Extremely Short Lactation Length (ESLL)

Logistic regression with backward elimination was performed to retain all the variables at a 5% level of significance for the risk factor identification for abnormal lactation length using SAS software version 9.3. Table 4.9 summarises the factors that were eliminated as they had no significant effect on extremely short lactation length (ESLL). Candidate risk factors viz. Foot and mouth disease, Udder swelling, Off feed, Vulvar wound, Abscess, Dystocia, Month of calving, Retention of placenta/ foetal membranes, Metritis, Weakness, Mastitis, Lameness, Repeat breeding, Udder wound, ROP, Other/rare diseases, Pyrexia, Premature birth, Leg wound, Pyometra and Diarrhoea showed no significant effect on ESLL at 5% level of significance.

Table 4.9: Summary of backward elimination of factors for extremely short lactation

Effect removed	df	Wald Chi-squares	Pr>ChiSq
Foot and mouth disease	1	0.0001	0.9909
Udder swelling	1	0.0002	0.9893
Off fed	1	0.0004	0.9842
Vulvar wound	1	0.0002	0.9874
Abscess	1	0.0007	0.9790
Dystocia	1	0.1142	0.7354
Month of calving	11	8.3211	0.6843
Metritis	1	0.2335	0.6289
Weakness	1	0.3873	0.5337
Lameness	1	0.5888	0.4429
Repeat breeding	1	0.8866	0.3464
Udder wound	1	0.9673	0.3254
Retention of placenta	1	1.1651	0.2804
Others	1	1.5739	0.2096
Pyrexia	1	1.7564	0.1851
Mastitis	1	1.8258	0.1766
Leg wound	1	1.9519	0.1624
Premature birth	1	2.6074	0.1064
Pyometra	1	2.9346	0.0867
Diarrhoea	1	3.7116	0.0540

Among the risk factors, Parity, Period of calving, Abortion, Stillbirth and Prolapse were found to impose ESLL (Table 4.10). When comparing the parity, the 3rd parity group had the greatest influence, with a value of 0.832 times greater than the 4th group (table 4.11). Dhandapani et al. (2020) reported a similar result in Nili ravi buffaloes, where the 3rd parity had the shortest lactation length. At a 5% level of significance, the 2nd parity had the smallest effect on the causation of ESLL when compared to the 4th parity group. Mehta (2020) conducted a similar study on crossbred cattle and found that parity had a substantial impact on ESLL. In contrast to the current outcome, the 4th parity group was found to have the greatest influence out of the 5 parity groups created. Among the different periods, 3rd period was found to have highest incidences of ESLL. Table 4.11 shows that animals having abortions had 46.132 times more likelihood of developing an ESLL than animals who had normal calving. Stillbirth and prolapse also had 14.03- and 3.77-times higher chances to cause ESLL. Abortion and stillbirth are two of the key reasons for the farm's financial loss. Infectious agents, such as bacterial or viral infections, or non-infectious causes, such as nutritional deficiency, pelvic abnormalities, accidents, and so on, can cause them. Whatever the cause, it reduces lactation milk yield and peak yield, both of which are directly correlated to lactation length (Keshavarzi et al., 2020; EL-Tarabany, 2015). No scientific study or proof of prolapse to cause ESLL was found so far.

Table 4.10: Maximum likelihood estimates of factors affecting extremely short lactation length

Parameter	Class	Df	ML Estimate ± S.E	Wald Chi-squares	Pr>ChiSq
Parity	Pa1	1	-0.0427± 0.1464	0.0520	0.8197
	Pa2	1	-0.5948± 0.2283	6.7876	0.0092
	Pa3	1	0.2266± 0.1929	1.3791	0.2403
Period of calving	P1	1	-0.3613± 0.2076	3.0304	0.0817
	P2	1	-0.6570± 0.2108	9.7151	0.0018
	P3	1	0.2796± 0.2130	1.7233	0.1893
Abortion	0	1	3.8315± 0.3260	138.1065	<.0001
Stillbirth	0	1	2.6393± 0.4231	38.9142	<.0001
Prolapse	0	1	1.3273± 0.5194	6.5298	0.0106

Table 4.11: Odds ratio of factors affecting extremely short lactation length

Effect	Class difference	Unit	Odds ratio	95% confidence limits
Parity	Pa1 vs Pa4	1	0.635	0.339 to 1.192
	Pa2 vs Pa4	1	0.366	0.177 to 0.754
	Pa3 vs Pa4	1	0.832	0.441 to 1.567
Period of calving	P1 vs P4	1	0.333	0.179 to 0.620
	P2 vs P4	1	0.248	0.132 to 0.465
	P3 vs P4	1	0.632	0.337 to 1.184
Abortion	1 vs 0	1	46.132	24.349 to 87.403
Stillbirth	1 vs 0	1	14.003	6.111 to 32.088
Prolapse	1 vs 0	1	3.771	1.362 to 10.437

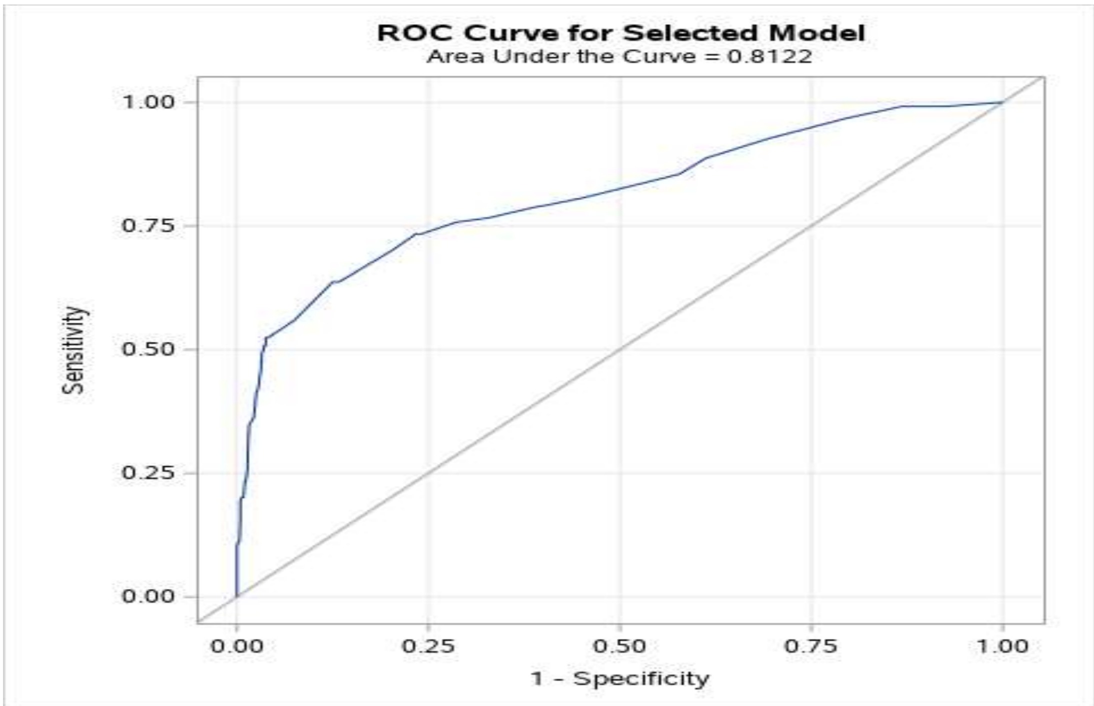

Figure 4.3: ROC curve for extremely short lactation length at 5% level of significance

Figure 4.3 shows the area under the receiver operating characteristic curve (ROC) of the selected model for ESLL at a 5% significance level. The graph indicates an area under the curve of 81.22 %, indicating that the model would provide 81.22 % accuracy of factors causing short lactation length at a 5% significance level. In other words, it demonstrates that the factors found significant will account for approximately 81.22 % of the causes of ESLL.

4.4.2 Short lactation length (SLL)

Pyometra, Metritis, Pre-mature birth, Dystocia, Abscess, Mastitis, Foot and mouth disease, Off feed, Vulva wound, Prolapse, Retention of placenta, Diarrhoea, Udder wound, Period of calving, Weakness, Others, Pyrexia, Lameness, Leg wound, and Repeat breeding were found to have no significant effect on short lactation at the 5% level of significance (Table 4.12).

Table 4.12: Summary of elimination of factors effect on short lactation

Effect removed	df	Wald Chi-squares	Pr>ChiSq
Pyometra	1	0.0000	0.9961
Metritis	1	0.0000	0.9950
Premature birth	1	0.0001	0.9919
Dystocia	1	0.0001	0.9906
Abscess	1	0.0003	0.9852
Mastitis	1	0.0001	0.9908
Foot and mouth disease	1	0.0002	0.9893
Off fed	1	0.0002	0.9880
Vulva wound	1	0.0003	0.9858
Prolapse	1	0.0004	0.9850
Retention of placenta	1	0.0003	0.9855
Diarrhoea	1	0.0074	0.9316
Udder wound	1	0.2277	0.6333
Period of calving	3	2.1573	0.5404
Pyrexia	1	0.9536	0.3288
Others	1	1.1178	0.2904
Lameness	1	1.5001	0.2207
Weakness	1	1.3145	0.2516
Leg wound	1	1.7313	0.1882
Repeat breeding	1	3.3568	0.0669

Table 4.13: Maximum likelihood estimates of factors affecting short lactation length

Parameter	Class	Df	ML Estimate±SE	Wald chi-squares	Pr>ChiSq
Parity	Pa1	1	-0.3721 ±0.2637	1.9906	0.1583
	Pa2	1	-0.5750±0.2846	4.0832	0.0433
	Pa3	1	0.3227±0.2276	2.0097	0.1563
Month of calving	Jan	1	-0.4027±0.5859	0.4723	0.4919
	Feb	1	-0.3362±0.6881	0.2387	0.6252
	Mar	1	0.3469±0.5292	0.4296	0.5122
	April	1	0.3191±0.6970	0.2095	0.6471
	May	1	-1.5227±1.0009	2.3146	0.1282
	June	1	-0.8331±0.7331	1.2914	0.2558
	July	1	-0.0218±0.5076	0.0018	0.9658
	Aug	1	0.4082±0.3759	1.1793	0.2775
	Sept	1	0.3822±0.4129	0.8568	0.3546
	Oct	1	1.1534±0.3562	10.4831	0.0012
	Nov	1	-0.6527±0.6958	0.8800	0.3482
Abortion	0	1	2.6112±0.5114	26.0704	<.0001
Stillbirth	0	1	1.7647±0.7055	6.2567	0.0124
Udder swelling	0	1	2.5458±0.7839	10.5479	0.0012

Table 4.14: Odds ratio estimates of factors affecting short lactation length

Effect	Class difference	Point estimate	95% confidence limits
Parity	Pa1 vs Pa4	0.369	0.166 to 0.821
	Pa2 vs Pa4	0.301	0.128 to 0.709
	Pa3 vs Pa4	0.740	0.367 to 1.488
Month of calving	Jan vs Dec	0.210	0.055 to 0.807
	Feb vs Dec	0.224	0.048 to 1.054
	Mar vs Dec	0.444	0.129 to 1.526
	April vs Dec	0.432	0.091 to 2.041
	May vs Dec	0.068	0.008 to 0.623
	June vs Dec	0.136	0.026 to 0.710
	July vs Dec	0.307	0.093 to 1.016
	Aug vs Dec	0.472	0.186 to 1.199
	Sept vs Dec	0.460	0.168 to 1.259
	Oct vs Dec	0.994	0.406 to 2.436
	Nov vs Dec	0.163	0.034 to 0.783
Abortion	1 vs 0	13.615	4.997 to 37.096
Stillbirth	1 vs 0	5.840	1.465 to 23.275
Udder swelling	1 vs 0	12.754	2.744 to 59.276

Figure 4.4 shows a 77.12% area under curve at a significance level of 5%. Parity, Month of calving, Abortion, Stillbirth and Udder swelling were found to have a significant effect on transitioning lactation length into SLL As indicated in the table 4.14, the 3rd parity group had the greatest effect on short lactation length (SLL) when compared to the 4th parity group, while the 2nd parity had the smallest effect. At a 5% level of significance, the month of calving was found to have a significant effect on SLL. Animals calved in October had the maximum likelihood of having a SLL, with 0.994 times higher possibilities than those calving in December, while those calving in May had the lowest likelihood. The current findings had been supported by Dass and Sadana (2000), stating that in Murrah buffaloes that the animals which calved during summer i.e., April-June showed longest lactation length with highest 305MY. Animals that calved in October are expected to reach peak yield during the winter season. Because winter stress reduces animal productivity (Upadhyay et al., 2007),

peak yield is likely to be low. Thus, lactation length is expected to be shorter as it is highly correlated with peak yield.

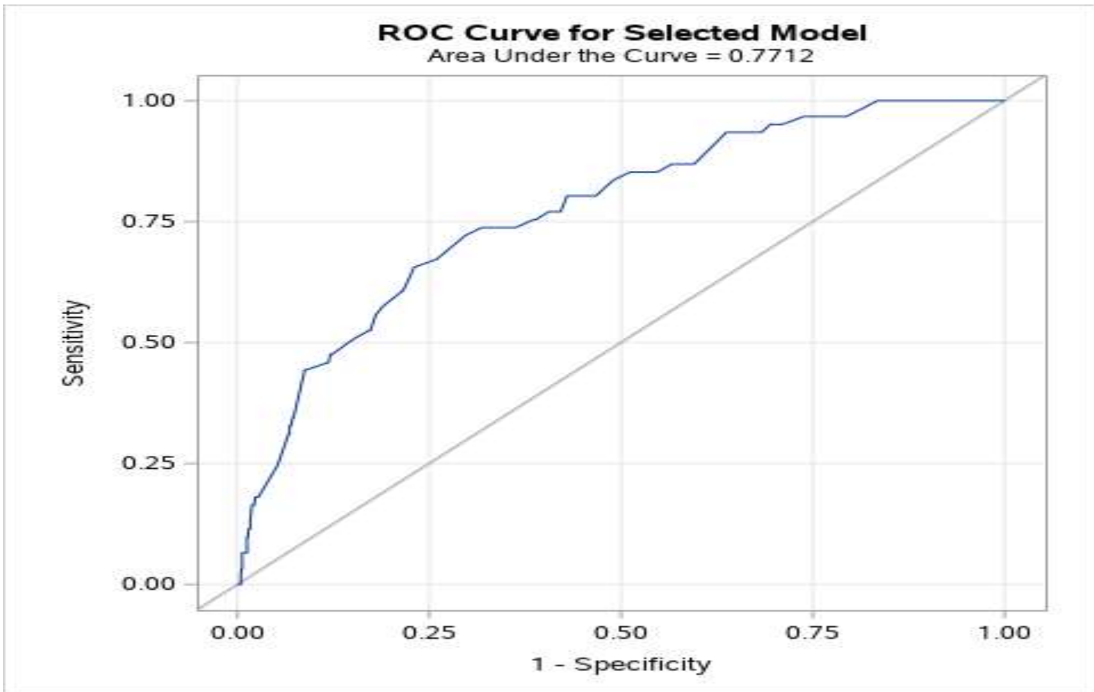

Figure 4.4: ROC curve for short lactation length at 5% level of significance

. In comparison to normal healthy animals, abortion had 13.615 times greater chances of causing SLL, while udder swelling had 12.754 times more chances of causing SLL. Stillbirth was also discovered to have a 5.84-fold influence on SLL when compared to animals that had normal calving. Mehta (2021) also noted that parity and udder swelling were known to cause SLL in crossbred cattle on the same farm investigated, thereby supported the current findings. The explanation for udder swelling could be cases like sub-clinical mastitis, which can go undiagnosed because no apparent indications of inflammation or changes in milk composition are visible, but can lead to a decrease in milk output (Sharma & Sindhu, 2007) and finally, may result in reduction of lactation length.

4.4.3 Extremely prolonged lactation (EPLL)

Table 4.15 shows the summary of elimination of effects at 5% level of significance where Pyometra, Uterine torsion, Metritis, Pre-mature birth, Foot and mouth disease, Udder swelling, Abortion, Stillbirth, Mastitis, Off fed, Weakness, Diarrhoea, Others, Vulva wound, Leg wound, Abscess, Month of calving, Pyrexia and Prolapse had no significant effect on extremely prolong lactation length (EPLL).

Table 4.15: Summary of elimination of factors effecting extremely prolonged lactation

Step	Effect removed	df	Wald Chi-squares	Pr>ChiSq
1.	Pyometra	1	0.0000	0.9963
2.	Torsion	1	0.0000	0.9993
3.	Metritis	1	0.0000	0.9945
4.	Premature birth	1	0.0002	0.9901
5.	Foot and mouth disease	1	0.0002	0.9894
6.	Udder swelling	1	0.0002	0.9889
7.	Abortion	1	0.0005	0.9826
8.	Stillbirth	1	0.0003	0.9871
9.	Mastitis	1	0.0026	0.9590
10.	Off fed	1	0.0028	0.9580
11.	Weakness	1	0.0066	0.9353
12.	Diarrhoea	1	0.0181	0.8929
13.	Others	1	0.0356	0.8504
14.	Vulva wound	1	0.0919	0.7618
15.	Leg wound	1	0.1510	0.6975
16.	Abscess	1	0.1819	0.6697
17.	Month of calving	11	11.8233	0.3771
18.	Pyrexia	1	1.7174	0.1900
19.	Prolapse	1	1.9849	0.1589

Table 4.16: Maximum likelihood estimates of factors affecting extremely prolonged lactation length

Parameter	**Class**	**Df**	**ML Estimate ± S.E**	**Wald chi squares**	**Pr>ChiSq**
Parity	Pa1	1	0.9839±0.2243	19.2417	<.0001
	Pa2	1	0.00404±0.2660	0.0002	0.9879
	Pa3	1	-0.2623±0.2753	0.9072	0.3409
Period of calving	P1	1	-0.3515±0.2673	1.7284	0.1886
	P2	1	0.0168±0.2271	0.0055	0.9410
	P3	1	0.9787±0.2321	17.7834	<.0001
Repeat breeding	0	1	1.6032±0.3168	25.6099	<.0001
Retention of placenta	0	1	1.3005±0.4380	8.8164	0.0030
Dystocia	0	1	2.0035±0.9480	4.4662	0.0346
Lameness	0	1	0.8878±0.3674	5.8402	0.0157
Udder wound	0	1	0.9472±0.3351	7.9904	0.0047

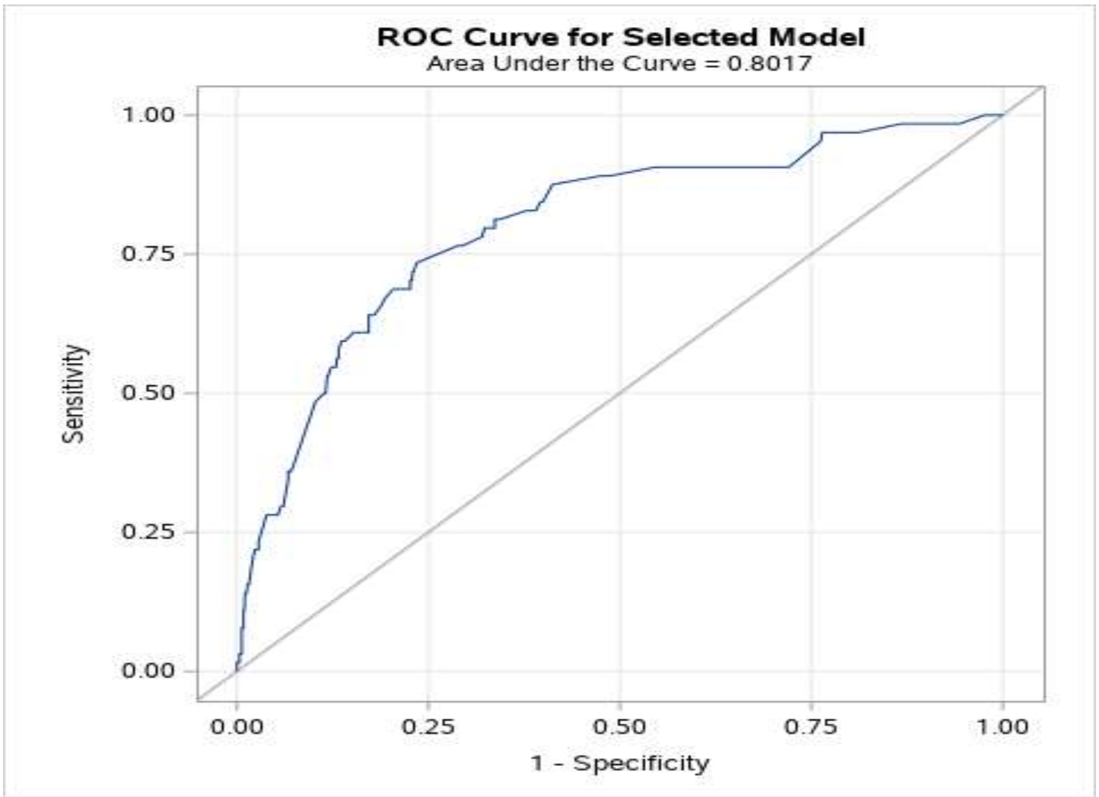

Figure 4.5: ROC curve for extremely prolonged lactation length at 5% level of significance

Table 4.17: Odds ratio estimates of factors affecting extremely prolonged lactation length

Effect	Class difference	Point estimate	95% confidence limits
Parity	Pa1 vs Pa4	5.526	2.137 to 14.290
	Pa2 vs Pa4	2.074	0.751 to 5.733
	Pa3 vs Pa4	1.589	0.561 to 4.504
Period of calving	P1 vs P4	1.340	0.482 to 3.726
	P2 vs P4	1.936	0.749 to 5.006
	P3 vs P4	5.067	1.958 to 13.113
Repeat breeding	1 vs 0	4.969	2.671 to 9.246
Retention of placenta	1 vs 0	3.671	1.556 to 8.662
Dystocia	1 vs 0	7.415	1.157 to 47.545
Lameness	1 vs 0	2.430	1.183 to 4.992
Udder wound	1 vs 0	2.578	1.337 to 4.973

An area under the curve of 80.17% (fig. 4.5), depicts that at a level of 5% significance, the factors that had a substantial influence explain approximately 80.17% of the reasons of EPLL period. Parity, Period of calving, Repeat breeding, ROP, Dystocia, Lameness and Udder wound were found to have significant effect on EPLL in accordance to table 4.16, which provides the findings of maximum likelihood estimates at a 5% level of significance. As the number of parity increased, a diminishing trend was found, with the 1st parity having the most influence, 5.526 times more than the 4th parity group and the 3rd parity group having the least effect when compared to the 4th parity group. The period of calving, on the other hand, showed an increasing trend as the years advanced. Animals calved in the first group i.e., 2005-2008, had the lowest chances of having EPLL when compared to the fourth group at a 5% significant level, whereas animals calved in the third group i.e., 2013-2016, had the highest rates of extremely prolong lactation. When compared to normal calving, animals with dystocia and retention of placenta had a higher likelihood of converting to prolong lactation length. Repeat breeders had a 4.969 times higher risk of transiting into EPLL than other animals with a normal conception rate (table 4.17).

A lack of $PGF_2\alpha$ and oxytocin secretions, as well as serum Calcium concentrations, which maintain the uterus contraction property, can cause retention of placenta, raise the risk of dystocia, and delay uterine involution (McDowell, 1992; Hurley et al., 1989) Therefore, as involution of uterus is delayed, conception rates decline and lactation length tends to prolong due to absence of pregnancy.

Lameness induces continuous pain as well as stress in animals, marked by a disturbance in the body's homeostasis, causes hyperalgesia and hampers the catabolic state of the body (Smart & Cymbaluk, 1997; Whay et al., 1997). Cattle under stress and discomfort produce large quantities of catecholamine’s, glucocorticoids, and stress-induced progesterone in their blood (Nanda et al., 1990; Watson et al., 1994). Increases in adrenocorticotrophic hormone, cortisol, and progesterone at slightly higher than normal levels have been linked to a delay or suppression of the Gonadotropin releasing hormone (GnRH), leading to change in normal ovarian follicular activity and the creation of persistent ovarian follicles (Nanda et al., 1990; Dobson et al., 2000; Noble et al., 2000). Repeat breeding is noticed as follicular activity is disrupted, and animal conception decreases. As previously stated, the absence of pregnancy causes a delay of dry period, resulting in a longer lactation duration. Meanwhile, in case of effect of udder wound, a broader perspective must be created. The significance of the effect of udder wound is more likely to be vice versa, implying that the health of the udder is harmed as a result of extremely long lactation, resulting in wound development. This possible scenario was also reported by Natzke et al. (1982) in which overmilking affects the udder health, creating a greater risk of infections.

4.4.4 Prolonged lactation length (PLL)

Pyometra, Dystocia, Foot and mouth disease, Diarrhoea, Metritis, Stillbirth, Vulva wound, Udder swelling, Weakness, Abortion, Pyrexia, ROP, Prolapse, Month of Calving, Off feed, Leg wound, Mastitis, Abscess, Udder wound, Others and Lameness were found to have no significant effect on prolonged lactation length (table 4.18). As indicated in figure 4.6, the area under the curve is 68.48%, implying that the current model would provide not so accurate estimate of factors causing prolong lactation length (PLL) at 5% significance level and there may be more individual and unexplained variability in occurrence of prolong lactations.

Table 4.18: Summary of elimination of factors effect on prolonged lactation

Step	Effect removed	df	Wald Chi-squares	Pr>ChiSq
1.	Pyometra	1	0.0000	0.9960
2.	Dystocia	1	0.0001	0.9940
3.	Foot and mouth disease	1	0.0001	0.9910
4.	Diarrhoea	1	0.0002	0.9894
5.	Metritis	1	0.0002	0.9893
6.	Stillbirth	1	0.0003	0.9858
7.	Vulva wound	1	0.0004	0.9845
8.	Udder swelling	1	0.0602	0.8061
9.	Weakness	1	0.1476	0.7008
10.	Abortion	1	0.1498	0.6988
11.	Pyrexia	1	0.1679	0.6820
12.	Retention of placenta	1	0.2001	0.6547
13.	Prolapse	1	0.1834	0.6685
14.	Month of calving	11	8.7043	0.6492
15.	Off fed	1	0.2031	0.6523
16.	Leg wound	1	0.5217	0.4701
17.	Mastitis	1	0.5617	0.4536
18.	Abscess	1	0.7232	0.3951
19.	Udder wound	1	0.7328	0.3920
20.	Others	1	0.8900	0.3455
21.	Lameness	1	1.6369	0.2007

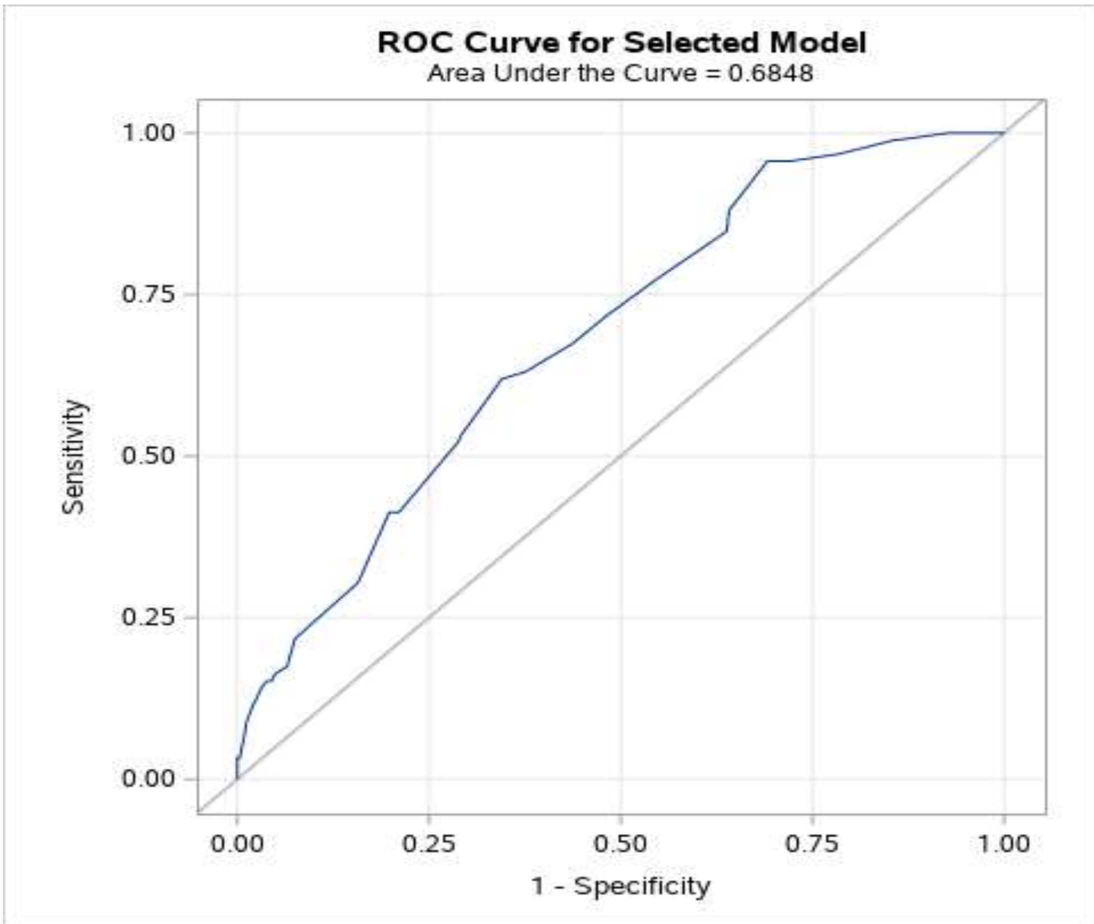

Figure 4.6: ROC curve for prolonged lactation length at 5% level of significance

Table 4.19: Maximum likelihood estimates of factors affecting prolonged lactation length

Parameter	Class	Df	ML Estimate ± S.E	Wald chi squares	Pr>ChiSq
Parity	Pa1	1	0.5762±0.1771	10.5885	0.0011
	Pa2	1	0.0872±0.2049	0.1811	0.6704
	Pa3	1	-0.1158±0.2091	0.3066	0.5798
Period of calving	P1	1	0.4376±0.1917	5.2114	0.0224
	P2	1	0.1881±0.1914	0.9663	0.3256
	P3	1	0.4361±0.2210	3.8957	0.0484
Premature birth	0	1	1.9558±0.8071	5.8729	0.0154
Repeat breeding	0	1	1.0089±0.2769	13.2734	0.0003

Table 4.20: Odds ratio estimates of factors affecting prolonged lactation length

Effect	Class difference	Point estimate	95% confidence limits
Parity	Pa1 vs Pa4	3.076	1.441 to 6.567
	Pa2 vs Pa4	1.887	0.839 to 4.241
	Pa3 vs Pa4	1.540	0.679 to 3.493
Period of calving	P1 vs P4	4.479	1.832 to 10.950
	P2 vs P4	3.490	1.425 to 8.547
	P3 vs P4	4.473	1.736 to 11.524
Repeat breeding	1 vs 0	7.070	1.454 to 34.385
Premature birth	1 vs 0	2.743	1.594 to 4.719

Parity, period of calving, repeat breeding and pre-mature birth were found to have an impact on PLL (Table 4.19). A decreasing trend was observed when number of parity increases (Table 4.20). When compared to the 4th parity group, the 1st parity had the highest chance of causing prolonged lactation length, with 3.838 times greater possibilities. Period of calving showed an irregular trend, with the 1st group having the highest chances of having PLL compared to the 4th group while the 2nd group had the lowest odds ratio. At a 5% level of significance, animals giving premature birth are found to have 2.743 times greater chances of acquiring prolonged lactation length. Repeat breeders are also predicted to have 7.07 times longer lactation than animals with a regular reproductive cycle. No scientific evidence or study of Premature birth causing PLL was found.

4.5 Mixed model analysis for factors affecting lactation length

Using Proc Mixed in the SAS software version 9.3, all factors considered in the present study explaining lactation length in Murrah buffaloes were analysed simultaneously as fixed effects and taking sire and animal within sire as random effects. The goal of this study was to see how the incidence and duration of various factors affected the normal lactation length quantitatively and caused it to change by incidence, duration and as a fraction of lactation. The mixed model procedure was repeated, with each step eliminating the non-significant factor having highest p value from the model, until all the factors remained in the model were found significant at 5% level of significance.

4.5.1 Frequency of disease

When analysed with a mixed model, parity, period of calving, month of calving, repeat breeding, abortion, stillbirth, retention of placenta, frequency of prolapse, lameness, udder swelling and vulvar wound all had a significant effect on lactation length at 5% level of significance (Table 4.21). According to the regression coefficients presented in table 4.22, it can be stated that per incidence of prolapse and udder swelling within a lactation cycle causes reduction of lactation length approximately by 37.474 days and 61.15 days respectively. On the contrary, occurrence of lameness during lactation was expected to lengthen the lactation period by 32.74 days.

Table 4.21: Test of fixed effects for lactation length with frequency of disease

Effect	Df	F value	Pr >F
Parity	3	22.36	<.0001
Period of Calving	3	21.15	<.0001
Month of calving	11	2.91	0.0009
Repeat breeding	1	10.36	0.0013
Abortion	1	269.38	<.0001
Stillbirth	1	67.10	<.0001
Retention of placenta	1	7.67	0.0058
Prolapse_F	1	4.63	0.0317
Lameness_F	1	27.74	<.0001
Udder swelling_F	1	4.90	0.0272

Table 4.22: Regression estimates for frequency of disease at 5% significant level

Effect	Regression Estimates ± S.E	Pr >│t│
Prolapse_F	-37.474± 17.410	0.0317
Lameness_F	32.74 ± 6.216	<.0001
Udder swelling_F	-61.156 ± 27.640	0.0272

The least squares mean of factors impacting lactation length significantly are shown in the table 4.23. A decreasing trend was found among the parity groups, with the first parity having the highest least squares mean and the fourth parity group (>4 parity) having the lowest.

Table 4.23: Least squares mean estimates of fixed effect at 5% level of significance

Effect	Class	Estimate ± S.E	Pr>│t│
Parity	Pa1	325.87^{a} ±12.94	<.0001
	Pa2	314.83^{a}±12.96	<.0001
	Pa3	281.12^{b} ±13.10	<.0001
	Pa4	261.70^{c} ±13.68	<.0001
Period of calving	P1	304.80^{a} ±13.11	<.0001
	P2	312.30^{a} ±12.87	<.0001
	P3	315.42^{a}±13.46	<.0001
	P4	250.99^{b}±13.67	<.0001
Month of calving	Jan	317.68^{a} ±14.95	<.0001
	Feb	318.83^{a} ±16.30	<.0001
	Mar	321.68^{a}±16.627	<.0001
	April	277.43^{e}±17.02	<.0001
	May	311.91^{abe}±16.91	<.0001
	June	293.27^{ade}±16.24	<.0001
	July	295.84^{ace}±15.34	<.0001
	Aug	285.89^{bcde}±14.23	<.0001
	Sept	273.35^{cde}±15.12	<.0001
	Oct	273.91^{cd}± 15.48	<.0001
	Nov	295.81^{ab}± 16.34	<.0001
	Dec	284.96^{bcde}± 14.96	<.0001
Repeat breeding	0	280.95^{b}±11.56	<.0001
	1	310.81^{a}±14.22	<.0001
Abortion	0	404.18^{a}±11.15	<.0001
	1	187.58^{b}±15.99	0.0414
Stillbirth	0	374.99^{a} ± 8.232	<.0001
	1	216.77^{b}± 20.29	0.0024
Retention of placenta	0	279.01^{b}±12.56	<.0001
	1	312.75^{a}±14.48	<.0001

In terms of calving period, an increasing trend was found until the third period, in which the maximum least squares mean was recorded but afterwards, drastic reduction was observed in the 4^{th} period. The lactation duration influenced by month of calving revealed an erratic pattern, with the highest least squares mean for lactation length affected by month of calving occurring in the third month i.e., March, and the least in September. The animals having retention of placenta and repeat breeding have higher least squares mean compared to animals free from it. Meanwhile, the animals which had abortion and stillbirth showed lower least squares mean as compared to animals having normal calving.

4.5.2 Duration of disease

Among the different disease duration after other fixed effects were adjusted, duration of prolapse, pyometra, and lameness had a significant effect on lactation length at a 5% level of significance (Table 4.24). From the regression estimates (table 4.25), it can be concluded that per day of prolapse causes reduction of lactation by 5.663 days while per day of pyometra reduced lactation period by 11.482 days. Per day of lameness however prolonged the lactation length by 2.851 days.

Table 4.24: Disease duration affecting lactation length at 5% level of significance

Effect	**Df**	**F value**	**Pr >F**
Prolapse_D	1	4.07	0.044
Lameness_D	1	16.30	<.0001
Pyometra_D	1	4.91	0.027

Table 4.25: Regression estimates for duration of disease at 5% significant level

Effect	**Regression Estimates ± S.E**	**Pr >│t│**
Prolapse_D	-5.663 ± 2.807	0.044
Lameness_D	2.851 ± 0.706	<.0001
Pyometra_D	-11.482 ± 5.183	0.0270

4.6 Consequences of abnormal lactation length on other traits

The effect of lactation length on other traits of next lactation cycle, as well as on contemporary production traits were estimated using general linear models (Proc GLM) followed by Post Hoc comparison of the least squares means.

4.6.1 Effect of lactation length on contemporary traits

Lactation yield, 305days milk yield, dry period and calving interval of the current lactation cycle were significantly affected by current lactation length at the 5% level of significance (Table 4.26). Jakhar et al. (2016) also reported a significant influence of lactation length stating that the influence of lactation length on performance attributes was extremely significant, showing that it plays a critical role in the animal's total performance. The least squares mean of lactation classes for lactation milk yield and 305-days milk yield affected by the current lactation length after adjustment of fixed effect at 5% significant level are presented from table 4.27 onwards.

Table 4.26: ANOVA table for traits affected by current lactation length

Factors effect	Df	Type III SS	Mean Square	F Value	Pr > F
Lactation Yield	4	382919624.3	95729906.1	191.92	<.0001
305-Days Milk yield	4	238280183.4	59570045.8	146.35	<.0001
Dry period	4	392761.6583	98190.4146	6.83	<.0001
Calving interval	4	945755.3574	236438.8394	13.19	<.0001

Table 4.27: Least squares means of lactation milk yield and 305day milk yield for current lactation classes

Current Lactation Length	Lactation milk yield		305 Day milk yield	
	N	(LS Mean ± S.E)	N	(LS Mean ± S.E)
Extremely prolonged lactation	60	3998.762^{a} ± 193.896	60	2826.614^{a} ± 175.153
Prolonged lactation	90	3160.014^{b} ± 169.991	90	2579.182^{a} ± 153.559
Normal lactation	941	2087.316^{c} ± 146.421	941	2024.478^{b} ± 132.267
Short lactation	65	701.157^{d} ± 174.615	65	696.116^{c} ± 157.737
Extremely short lactation	79	184.486^{e} ± 170.942	79	165.690^{d} ± 154.418

The least squares mean for lactation milk yield in all lactation length classes differ significantly at the 5% level of significance and was highest for extremely prolonged lactation length. The normal lactation length, short lactation length, and finally extremely short lactation classes followed in a decreasing order for lactation milk yield (Table 4.27). For 305-day milk yield, extremely prolonged lactation length and prolonged lactation length did not differ to each other and had the highest least squares mean followed by normal, short, and extremely short lactation classes. With the exception of prolonged and extremely prolonged lactation length, all lactation lengths showed a significant difference at 5% level (Table 4.27).

The maximum least squares mean for calving interval was found in extremely prolonged lactation length, followed by prolonged lactation, normal, short, and extremely short lactation length (Table 4.28). At the 5% level of significance, there was no significant difference in least squares mean between extremely prolong, long, and short lactation length. The distinction between extremely short lactation, short lactation, and normal lactation was also found to be insignificant.

Table 4.28: Least squares means of calving interval and dry period for current lactation cycle

Current Lactation Length	Calving interval		Dry Period	
	N	(LS Mean ± S.E)	N	(LS Mean ± S.E)
Extremely prolonged lactation	38	$646.603^{a} \pm 50.554$	36	$123.713^{a} \pm 45.294$
Prolonged lactation	62	$596.194^{a} \pm 41.184$	62	$193.459^{ab} \pm 36.891$
Normal lactation	711	$454.436^{b} \pm 35.949$	698	$133.372^{a} \pm 32.211$
Short lactation	28	$442.973^{b} \pm 47.603$	27	$275.209^{b} \pm 42.640$
Extremely short lactation	20	$418.299^{ab} \pm 102.845$	14	$351.288^{ab} \pm 92.137$

According to the table 4.28, extremely short lactation length had the highest least squares mean for dry period among different lactation classes, followed by short lactation, prolonged lactation, normal, and extremely prolonged lactation length. At the 5% significance level, no significant differences were found between extremely prolonged, prolonged, normal, and extremely short lactation length, while extremely prolonged and normal lactation length differ significantly from short lactation length. There were no significant differences in least squares mean between lactation length that were extremely short, short, and long.

4.6.2 Effect of previous lactation length

After adjusting the traits for fixed effect, it was observed that the previous lactation length had a significant impact on weight at calving, lactation milk yield, 305 lactation milk yield, peak yield, and the service period of the next lactation cycle (Table 4.29).

Table 4.29: ANOVA table for traits affected by previous lactation length

Factor effect	DF	Type III SS	Mean Square	F Value	Pr > F
Lactation yield	4	53573898.38	13393474.60	14.09	<.0001
305 milk yield	4	29855923.57	7463980.89	10.77	<.0001
Peak yield	4	351.9460009	87.9865002	7.20	<.0001
Service period	4	3070795.212	767698.803	59.66	<.0001
Weight at calving	4	72931.2811	18232.8203	3.38	0.0094

For lactation milk yield, the least squares mean of next lactation affected by prior cycle was highest in extremely prolong lactation length and significantly different from all the other classes. Normal lactation length differed significantly from extremely long, extremely short, and short lactation lengths, but was insignificant when compared to prolong lactation length. At 5% level of significance, there was no significant difference in the least square means between extremely short and short lactation length. The least squares mean of 305-day milk yield followed the same pattern as lactation milk yield, with similar significant differences throughout the lactation classes.

Table 4.30: Least squares means of lactation milk yield and 305-day milk yield of next lactation

Previous Lactation Length	Lactation milk yield		305 Day milk yield	
	N	(LS Mean ± S.E)	N	(LS Mean ± S.E)
Extremely prolonged lactation	31	2785.090^{a}±261.915	31	2298.519^{a}±223.621
Prolonged lactation	58	1971.540^{b}±232.532	58	1734.377^{b}±198.534
Normal lactation	626	1747.595^{b}±197.012	626	1617.173^{b}±168.207
Short lactation	23	877.761^{c}±311.651	23	857.716^{c}±266.085
Extremely short lactation	15	970.217^{c}±329.579	15	935.619^{c}±281.392

In accordance to table 4.31, maximum least squares mean for peak yield of following lactation cycle was observed in extremely prolonged lactation length and was significantly different from the other lactation classes. Normal, prolonged, and extremely short lactation lengths, on the other hand, showed no significant variations. Short lactation length did not differ significantly from extremely short lactation length; however, it did differ significantly from normal and prolonged lactation length at the 5% significance level.

Table 4.31: Least squares means of peak yield for next lactation

Previous Lactation Length	**Peak yield**	
	N	**(LS Mean ± S.E)**
Extremely prolonged lactation	30	13.349^{a} ±0.952
Prolonged lactation	57	11.145^{b}±0.844
Normal lactation	620	10.978^{b}±0.715
Short lactation	23	8.370^{c}±1.123
Extremely short lactation	15	8.529^{bc}±1.187

Extremely prolonged lactation length of the previous cycle had the longest service period in the next cycle among the lactation groups (table 4.32) followed by service period for prolonged lactation length which differed from all the other lactation classes significantly (P≤0.05). There were no significant differences in length of service period between normal lactation, short lactation, and extremely short lactation length.

Table 4.32: Least squares means of service period for next lactation length

Previous Lactation Length	**Service period**	
	N	**(LS Mean ± S.E)**
Extremely prolonged lactation	32	402.834^{a}±30.295
Prolonged lactation	57	330.993^{b}±26.517
Normal lactation	619	155.874^{c}±22.673
Short lactation	22	127.073^{c}±36.100
Extremely short lactation	15	139.284^{c}±38.213

The least squares mean of average weight at calving for extremely prolonged lactation class was significantly higher than normal lactation (P≤0.05); however, there were no significant differences among all other lactation classes (Table 4.33).

Table 4.33: Least squares means of weight at calving for next lactation

Previous Lactation Length	Weight at calving	
	N	(LS Mean ± S.E)
Extremely prolonged lactation	30	623.298^{a}±21.112
Prolonged lactation	57	601.574^{ab}±18.060
Normal lactation	619	581.216^{b}±15.629
Short lactation	22	605.800^{ab}±24.031
Extremely short lactation	15	603.846^{ab}±25.888

4.7 Estimation of genetic parameters

Heritability of important economic traits was estimated using the sire model by BLUPF90 software while correlation was estimated using SAS software 9.3 version. To determine which technique is better, two sets of data were used: raw and standardised. Raw data includes all data without any exceptions, whereas standardised data is made up of records that are free of anomalies. Only records of animals who finished their lactations during the herd life were used in the study.

Table 4.34: Summarisation of raw and standardized data

Data	Raw data	Standardized data
No. of Sires	164	151
No. of Animals	469	434
No of Lactations	1235	1104

Table 4.35: Descriptive statistics of raw and standardized data

Traits	N	Raw Data	N	Standardized Data
Lactation Length (days)	1235	295.88 ± 3.42	1104	318.74 ± 2.66
Lactation Yield (kg)	1235	2229.60 ± 28.78	1104	2343.73 ± 24.19
305- Days Milk Yield (kg)	1235	2060.26 ± 23.63	1104	2186.27 ± 20.00
Peak Yield (days)	1194	12.53 ± 0.10	1098	12.88 ± 0.10
Average Fat (%)	929	7.722 ± 0.067	862	7.74 ±0.08
Service Period (days)	979	171.44 ± 4.27	888	168.58 ± 4.45
Conception rate (%)	1214	65.91 ± 0.01	1084	66.37 ± 0.001

Table 4.36 contains the heritability and correlation between traits for standardized data and table 4.37 contains for raw data. Heritability is represented by diagonal values, genetic correlation by the upper diagonal and below diagonal represents the phenotypic correlation.

4.7.1 Lactation length

In standardized data, the estimated heritability for lactation length was 0.111±0.021 while raw data had a lower heritability of 0.053±0.018. In the same herd with different duration, Malhotra (2015) reported a low heritability of 0.125±0.090 for first lactation length. Malhado et al. (2013) and Jakhar et al. (2016) observed 0.15±0.03 and 0.12±0.09 in the same breed, which matches the current results. Low heritability of lactation length indicates that it is highly influenced by non-genetic factors. As a result, improvements in environmental factors such as feeding and management might improve the trait. Moreover, to improve through selection, family selection or progeny selection can be suggested.

Lactation length had a significant (P≤0.01) and high positive genetic correlation with lactation milk yield (0.769±0.058), 305-day milk yield (0.985±0.015), peak yield (0.529±0.077) and a moderate correlation with average fat percentage (0.354±0.085) in standardised data while conception rate had a negative genetic correlation (-0.607±0.072) with lactation length. Furthermore, a significant with positive genetic correlation was found between lactation length with service period (0.212±0.07) in raw data. Jakhar et al. (2016) reported similar genetic correlation of lactation length with lactation milk yield (0.795±0.059) and 305-day milk yield (0.631±0.095), while Malhotra (2014) found a higher genetic correlation of first lactation length with lactation milk yield (0.94±16) for the current farm under study.

A significant (P≤0.01) phenotypic correlation of lactation length with lactation milk yield and 305-day milk yield was observed where a positive and high correlation was found between lactation length with lactation milk yield (0.761±0.021) and 305-day milk yield (0.587±0.027) in standardized data. In raw data, lactation length was observed to have significant phenotypic correlation (P≤0.01) with lactation yield (0.837±0.015), 305-day milk yield (0.714±0.020), peak yield (0.369±0.026) and service period (0.210±0.031). Malhotra (2014) reported a high phenotypic correlation between first lactation length with lactation milk yield (0.76), 305-day milk yield (0.48) and peak yield (0.16) in Murrah buffaloes. Jakhar et al. (2016) also estimated similar phenotypic correlation of lactation length with lactation milk yield (0.722±0.686) and 305-day milk yield (0.482±0.376).

4.7.2 Lactation milk yield

The estimated heritability for lactation milk yield was determined to be 0.314±0.095 in standardised data and 0.161±0.044 in raw data, as shown in tables 4.44 and 4.45. Malhotra (2014) reported the same estimated value of 0.364±0.114 for lactation milk yield in the same farm, which was further supported by Barros et al. (2014) findings of 0.3.

Lactation milk yield was found to have a significant (P≤0.01) and high genetic correlation with 305-day milk yield (0.985±0.015) and peak yield (0.782±0.057). However, it had a moderate correlation with average fat percentage (0.245±0.088) and service period (0.329±0.086) in standardised data. Whereas conception rate was found to have a significant (P≤0.01) and a high negative correlation (-0.792±0.055) with lactation milk yield. Raw data also revealed a significant genetic correlation of lactation milk yield with 305-day milk yield (0.718±0.053), average fat percent (0.310±0.073) and peak yield (0.163±0.076).

In terms of phenotypic correlation, lactation milk yield had significant phenotypic correlation (P≤0.01) with 305-day milk yield (0.952±0.010) and peak yield (0.123±0.033) in standardized data. Lactation milk yield was also found to have a significant (P≤0.01) phenotypic correlation with 305-day milk yield (0.948±0.009), peak yield (0.651±0.021) and service period (0.174±0.031) in raw data. Jakhar et al. (2016) found the same results as raw data i.e., a phenotypic correlation between lactation milk yield with 305-day milk yield (0.904±0.85) and peak yield (0.669±0.412) for Murrah buffaloes.

Table 4.36: Heritability (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlation for standardized data

Traits	Lactation Length	Lactation Milk Yield	305days Milk Yield	Peak Yield	Fat Percentage	Service Period	Conception Rate
Lactation Length	**0.111±0.021**	0.769±0.058**	0.693±0.066**	0.529±0.077**	0.354±0.085**	0.143± 0.090	-0.607±0.072**
Lactation Milk Yield	0.761±0.021**	**0.314±0.095**	0.985±0.015**	0.782±0.057**	0.245±0.088**	0.329±0.086**	-0.792±0.055**
305days Milk Yield	0.587±0.027**	0.952±0.010**	**0.361±0.09**	0.808±0.053**	0.203±0.089*	0.303±0.087**	-0.818±0.052**
Peak Yield	-0.041±0.033	0.123±0.033**	0.173±0.033**	**0.204±0.038**	0.316±0.087**	0.456±0.081**	-0.741±0.061**
Fat Percentage	0.050±0.033	0.021±0.033	0.018±0.033	0.029±0.033	**0.415±0.061**	0.0912±0.0912	-0.132±0.090
Service Period	-0.115±0.033	-0.052±0.0334	0.010±0.033	0.090±0.033**	0.024±0.033	**0.128±0.009**	-0.336±0.086**
Conception Rate	-0.050±0.033	-0.061±0.033	-0.050± 0.033	-0.010± 0.033	-0.0001±0.033	0.149±0.0331	**0.081±0.026**

*Significant at 5% level

**Significant at 1% level

Table 4.37: Heritability (diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlation for raw data

Traits	Lactation Length	Lactation Milk Yield	305days Milk Yield	Peak Yield	Fat Percentage	Service Period	Conception Rate
Lactation Length	**0.053±0.018**	-0.042±0.077	0.007±0.077	-0.055±0.077	0.025±0.077	0.212±0.07**	-0.095±0.077
Lactation Milk Yield	0.837±0.015**	**0.161±0.044**	0.718±0.053**	0.163±0.076*	0.310±0.073**	0.019±0.077	0.285±0.074
305days Milk Yield	0.714±0.020**	0.948±0.009**	**0.222 ± 0.052**	0.398±0.071**	0.195±0.076**	-0.137±0.076	0.124±0.077
Peak Yield	0.369±0.026**	0.651±0.021**	0.725±0.019**	**0.151 ±0.039**	0.369 ±0.026**	0.651±0.021**	0.725 ±0.019
Fat Percentage	0.028±0.032	0.047±0.032	0.057±0.032	0.081±0.032**	**0.293± 0.067**	0.279±0.074**	0.028±0.032
Service Period	0.210±0.031**	0.174±0.031**	0.101±0.032**	0.010±0.032	0.020±0.036	**0.099± 0.073**	-0.073±0.077
Conception Rate	-0.019±0.028	-0.025±0.029	-0.019±0.029	0.006±0.029	0.072±0.033	-0.508±0.027**	**0.061 ± 0.045**

*Significant at 5% level

**Significant at 1% level

4.7.3 305-day milk yield

The estimated heritability for 305-day milk yield in standardised data was 0.361±0.09; while in raw data, it was estimated to be lower as 0.222±0.052. Malhotra (2014) and Raina (2015), on the other hand, both reported a heritability of near 0.4 in the same herd at earlier studies. In standardized data, there was a significant ($P \leq 0.01$) genetic correlation of 305-day milk yield with peak yield (0.808±0.053) as well as with service period (0.303±0.087), whereas a lower but significant ($P<0.05$) correlation was discovered with average fat percentage (0.203±0.089). In contrast, a negative genetic correlation was observed between 305-day milk yield and conception rate (-0.818±0.052). Meanwhile, at low estimates, average fat percentage (0.195±0.076) and peak yield (0.398±0.071) were found to have a significant ($P \leq 0.01$) genetic correlation with 305-day milk yield in raw data.

Similarly, in raw data, a significant ($P \leq 0.01$) phenotypic correlation between 305-day milk yield and peak yield (0.725±0.019) was observed. Service period was also found to have significant ($P \leq 0.01$) but low phenotypic correlation with 305-day milk yield (0.101±0.032). Standardized data revealed the same findings, i.e., a phenotypic correlation between 305-day milk yield and peak yield but with lower estimates (0.173±0.033). The findings were similar to the reports of Malhotra (2014) in which a positive genetic and phenotypic correlation of 305-day milk yield with peak yield was found in the current farm with different durations.

4.7.4 Peak yield

The heritability for peak yield in standardised data was calculated to be 0.204±0.038, while it was found to be 0.151±0.039 in raw data. In both sets of data, the heritability was low. Similar estimates were observed by Malhotra (2014) in the same farm i.e., 0.225± 0.099. In standardized data, peak yield was found to have a significant ($P \leq 0.01$) and positive genetic correlation with average fat percentage (0.316±0.087) and service period (0.456±0.081) but was found to have a negative correlation with conception rate (-0.741±0.061). Raw data revealed the same results wherein peak yield had a significant positive genetic correlation with service period (0.651±0.021) and average fat percentage (0.369 ±0.026).

According to standardized data, peak yield was estimated to have a significant (P≤0.01) phenotypic correlation with service period (0.090±0.033) whereas in raw data average fat percentage was found to have low but significant correlation with peak yield (0.081±0.032). However, a significant negative phenotypic correlation between peak yield and service period (-0.023±-0.182) was found by Jakhar et al. (2016).

4.7.5 Average fat percentage

The heritability of average fat percentage was moderate for standardized data, with a value of 0.415±0.061, and low for raw data, with a value 0.293± 0.067. However, Malhotra (2014) reported a higher heritability estimate of 0.611±0.119 for average fat percentage in the same farm. In raw data, a significant genetic correlation (P≤0.01) was found between average fat percentage and service period (0.279±0.074).

4.7.6 Service period

In standardised data, the service period had a heritability of 0.128±0.009, however in raw data, service period showed a heritability of 0.099± 0.073.

A highly significant (P≤0.01) and negative genetic (-0.336±0.086) correlation between service period and conception rate was observed in standardized data. Meanwhile, in raw data, a negative phenotypic correlation was also found between service period and conception rate with an estimated value of –0.508±0.027.

4.7.7 Conception rate

The heritability estimated for conception rate was low in both the data analysed i.e., 0.081±0.026 for standardized data and 0.061 ± 0.045 for raw data respectively. The genetic and phenotypic correlations of conception rate have already been discussed above.

4.8 Sire ranking

Using the spearman rank correlation method in SAS software version 9.3, the effect of data exclusion or standardisation on ranking of sire was assessed. Based on the sire's breeding values between the same traits, the correlation between the two sets of data was estimated. Lactation length, lactation milk yield, 305-day milk yield, and peak yield all showed a significant but low correlation (Table 4.38). The poor correlation suggests that there is a significant distinction between the two sets of data, and that there will be significant differences in the outcomes. As a result, standardization of daughters' records can have a significant impact on sire breeding value estimation. However, Canaza-Cayo et al. (2016) found no significant differences between inclusion and exclusion of short lactation length records in their study involving Girolando cattle.

Table 4.38: Sire rank correlation between raw data and standardized data

Trait	Spearman rank correlation	Pr>F
Lactation length	-0.183 ± 0.008	0.0447
Lactation milk yield	0.178 ± 0.008	0.0509
305-day milk yield	0.506 ± 0.007	<.0001
Peak yield	0.327 ±0.007	0.0003
Average fat percent	-0.148 ± 0.008	0.1054
Service period	0.003 ± 0.008	0.9728
Conception rate	0.095 ± 0.008	0.2985

Sires with up to 3 daughter's records were excluded from the ranking as the results may be inaccurate due to insufficiency of records. When sires were ranked for lactation length, lactation milk yield and 305-day milk yield, a significant difference was observed between the two sets of data. The results of these three major production parameters clearly showed that the truncation of data resulted in considerable variations in sire breeding value evaluation. Thus, for accurate rankings, breeding values based on overall performances without any exclusion of data should be preferred, even if daughters of a certain sire showed some anomalies such as short lactation length or prolong lactation and abnormalities in the type of calving.

Table: 4.39: Ranking of top 10 sires based on breeding values of lactation length

Rank	Sires	Daughters	ESL	SL	PL	EPL	AB	PB	SB
Standardized Data									
1.	M1524	10	0.15	0.00	0.1	0.00	0.15	0.05	0.00
2.	M2062	5	0.18	0.18	0.00	0.09	0.00	0.00	0.00
3.	MU3567	6	0.00	0.13	0.09	0.13	0.04	0.00	0.00
4.	M2176	8	0.27	0.09	0.00	0.09	0.18	0.00	0.18
5.	M1749	4	0.00	0.00	0.08	0.08	0.00	0.00	0.00
6.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
7.	M1354	6	0.06	0.00	0.06	0.13	0.06	0.00	0.00
8.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
9.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00
10.	M2459	4	0.2	0.00	0.2	0.00	0.20	0.00	0.00
Raw Data									
1.	MU1419	5	0.05	0.05	0.00	0.00	0.00	0.05	0.05
2.	M1994	4	0.1	0.1	0.2	0.1	0.00	0.10	0.10
3.	M2177	10	0.05	0.14	0.27	0.00	0.14	0.00	0.00
4.	M2176	8	0.27	0.09	0.00	0.09	0.18	0.00	0.18
5.	M1524	10	0.15	0.00	0.1	0.00	0.15	0.05	0.00
6.	MU5516	5	0.13	0.00	0.07	0.07	0.07	0.00	0.00
7.	M2234	7	0.00	0.06	0.06	0.00	0.00	0.00	0.06
8.	MU4059	4	0.38	0.00	0.00	0.00	0.25	0.00	0.00
9.	M2412	5	0.33	0.17	0.00	0.00	0.33	0.00	0.00
10.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00

In the table ESL: extremely short lactation, SL: Short lactation, PL: Prolong lactation, EPL: Extremely prolong lactation, AB: Abortion, SB: Stillbirth, PB: Premature birth

Table: 4.40: Ranking of top 10 sires based on breeding values of lactation milk yield

Rank	Sires	Daughters	ESL	SL	PL	EPL	AB	PB	SB
Standardized Data									
1.	M1524	10	0.15	0.00	0.1	0.00	0.15	0.05	0.00
2.	MU3567	6	0.00	0.13	0.09	0.13	0.04	0.00	0.00
3.	M2062	5	0.18	0.18	0.00	0.09	0.00	0.00	0.00
4.	M2176	8	0.27	0.09	0.00	0.09	0.18	0.00	0.18
5.	M1749	4	0.00	0.00	0.08	0.08	0.00	0.00	0.00
6.	M1354	6	0.06	0.00	0.06	0.13	0.06	0.00	0.00
7.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00
8.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
9.	M2177	10	0.05	0.14	0.27	0.00	0.14	0.00	0.00
10.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
Raw Data									
1.	MU3567	6	0.00	0.13	0.09	0.13	0.04	0.00	0.00
2.	M2062	5	0.18	0.18	0.00	0.09	0.00	0.00	0.00
3.	M2234	7	0.00	0.06	0.06	0.00	0.00	0.00	0.06
4.	MU5710	5	0.14	0.00	0.07	0.36	0.07	0.00	0.07
5.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
6.	M1749	4	0.00	0.00	0.08	0.08	0.00	0.00	0.00
7.	M1524	10	0.15	0.00	0.1	0.00	0.15	0.05	0.00
8.	MU1933	6	0.19	0.00	0.14	0.1	0.10	0.00	0.00
9.	MU1153	5	0.13	0.13	0.00	0.25	0.13	0.00	0.00
10.	MU1944	6	0.06	0.00	0.06	0.00	0.00	0.00	0.06

In the table ESL: extremely short lactation, SL: Short lactation, PL: Prolong lactation, EPL: Extremely prolong lactation, AB: Abortion, SB: Stillbirth, PB: Premature birth

Table 4.41: Ranking of top 10 sires based on breeding values of 305-day milk yield

Rank	Sires	Daughters	ESL	SL	PL	EPL	AB	PB	SB
Standardized Data									
1.	M1524	10	0.15	0.00	0.10	0.00	0.15	0.05	0.00
2.	MU3567	6	0.00	0.13	0.09	0.13	0.04	0.00	0.00
3.	M2062	5	0.18	0.18	0.00	0.09	0.00	0.00	0.00
4.	M2176	8	0.27	0.09	0.00	0.09	0.18	0.00	0.18
5.	M1749	4	0.00	0.00	0.08	0.08	0.00	0.00	0.00
6.	M1354	6	0.06	0.00	0.06	0.13	0.06	0.00	0.00
7.	M2177	10	0.05	0.14	0.27	0.00	0.14	0.00	0.00
8.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00
9.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
10.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
Raw Data									
1.	MU3567	6	0.00	0.13	0.09	0.13	0.04	0.00	0.00
2.	M1994	4	0.10	0.10	0.20	0.10	0.00	0.10	0.10
3.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00
4.	M2177	10	0.05	0.14	0.27	0.00	0.14	0.00	0.00
5.	M1524	10	0.15	0.00	0.10	0.00	0.15	0.05	0.00
6.	M2062	5	0.18	0.18	0.00	0.09	0.00	0.00	0.00
7.	M1727	4	0.06	0.13	0.13	0.00	0.00	0.00	0.06
8.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
9.	M2459	4	0.20	0.00	0.20	0.00	0.20	0.00	0.00
10.	MU4371	6	0.15	0.00	0.08	0.15	0.08	0.00	0.00

In the table ESL: extremely short lactation, SL: Short lactation, PL: Prolong lactation, EPL: Extremely prolong lactation, AB: Abortion, SB: Stillbirth, PB: Premature birth

The proven bulls of the current farm under study were ranked using raw data for lactation milk yield and 305-day milk yield. The same criteria were applied i.e., ranking based on breeding values and exclusion of sires up to three daughters due to insufficient records. As a result, 8 bulls were graded according to the incidences of aberrant lactation and type of calving in their daughters' performance. Out of the proven bulls listed, M1506 and M1875 are recommended to be handled with great caution in accordance to their daughters' performances.

Table 4.42: Ranking of current proven bulls based on breeding values of lactation milk yield

S. No.	Sires	Daughters	ESL	SL	PL	EPL	AB	PB	SB
1.	M2234	7	0.00	0.06	0.06	0.00	0.00	0.00	0.06
2.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
3.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
4.	M1875	8	0.28	0.00	0.00	0.06	0.11	0.00	0.00
5.	M1354	6	0.06	0.00	0.06	0.13	0.06	0.00	0.00
6.	M1994	4	0.10	0.10	0.20	0.10	0.00	0.10	0.10
7.	M2185	4	0.20	0.00	0.07	0.13	0.07	0.07	0.00
8.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00

In the table ESL: extremely short lactation, SL: Short lactation, PL: Prolong lactation, EPL: Extremely prolong lactation, AB: Abortion, SB: Stillbirth, PB: Premature birth

Table: 4.43: Ranking of current proven bulls based on breeding values of 305-day milk yield

S. No.	Sires	Daughters	ESL	SL	PL	EPL	AB	PB	SB
1.	M1994	4	0.10	0.10	0.20	0.10	0.00	0.10	0.10
2.	M2269	13	0.11	0.07	0.00	0.07	0.07	0.00	0.00
3.	M1796	6	0.00	0.06	0.00	0.18	0.00	0.00	0.06
4.	M2234	7	0.00	0.06	0.06	0.00	0.00	0.00	0.06
5.	M1506	4	0.17	0.17	0.33	0.00	0.33	0.00	0.00
6.	M1875	8	0.28	0.00	0.00	0.06	0.11	0.00	0.00
7.	M1354	6	0.06	0.00	0.06	0.13	0.06	0.00	0.00
8.	M2185	4	0.20	0.00	0.07	0.13	0.07	0.07	0.00

In the table ESL: extremely short lactation, SL: Short lactation, PL: Prolong lactation, EPL: Extremely prolong lactation, AB: Abortion, SB: Stillbirth, PB: Premature birth

CHAPTER – V

SUMMARY AND CONCLUSIONS

Lactation length in dairy animals has historically been disregarded despite its importance in the performance of animals due to low heritability and high genetic correlation with milk yield. It had been overlooked due to the widespread standardization and normalization approaches involving lactation length, thereby obscured the vast variation that exist. Murrah breeds being the most preferred breeds by the farmers owing to its high milk yielding capacity and excellent genetic potential had been chosen for the current investigation.

The current study was conducted at Directorate of Livestock Farms, GADVASU, Ludhiana with the following goals in mind: to identify the incidences and risk factors for abnormal lactation length, to estimate the consequences of abnormal lactation lengths on the performance of buffaloes, and to evaluate the impact of abnormal lactation lengths on genetic parameters. From 2005 to 2020, data on 1235 lactation records pertaining to 470 Murrah buffaloes were collected, along with any disease and disorders observed within those lactation periods. During the lactation period, 2211 such incidences were documented ranging from wounds to terminal diseases, together with their duration and frequency of occurrence.

The current herd of Murrah buffaloes was projected to have a mean lactation length of 295.886 ± 3.420 days in all-inclusive data. Lactation milk yield was 2229.604 ± 28.785 kg on average, whereas 305-day milk yield was 2060.268 ± 23.639 kg on average. The mean peak yield was 12.53 ± 0.1 kg, with on an average 47.344 ± 1.055 days to achieve peak yield. The average fat percent was calculated to be 7.722 ± 0.067%. The average service period was 171.446 ± 4.273 days and the dry period was projected to be 160.211 ± 4.3 days on average.

The lactation length of the data was divided into five groups based on their divergence from the mean. Lactation periods of less than 116 days were deemed extremely short, while lactation periods of 116 to 176 days were termed short lactation. Normal lactation length was defined as a range from 177 to 416 days. Lactation lasting 417 to 477 days was classed as prolong lactation, while lactation lasting more than 477 days was classified as extremely prolong lactation. The normal group encompasses 76.19 percent of the data collected. Short lactation length accounts for 5.26 percent of the overall lactation length studied, whereas extremely short lactation accounts for 6.4 percent. 7.29 percent of 1235 lactation records were determined to be prolong lactation, while 4.86 percent were found to be highly prolong lactation.

Pyrexia, Udder wound, Mastitis, Leg wound, Lameness, and Repeat breeding were among the major incidences/diseases observed out of 2211-recorded incidences over the period of 16 years. Mastitis and Udder wound occurrences were 9.36 percent and 9.86 percent, respectively, whereas Lameness and Leg wound incidences were 7.06 and 7.51 percent. Repeat breeding accounted for 6.78 percent of total incidents, while pyrexia accounted for 42.70 percent.

Using SAS software version 9.3, a logistic backward analysis was done on the risk factors for abnormal lactation length at a 5% level of significance. Parity, Calving period, Abortion, Stillbirth, and Prolapse all played a role in the causing extremely short lactation length, with an AUC of 81.22 percent. Short lactation was found to be significantly associated to Parity, Month of calving, Abortion, Stillbirth, and Udder swelling, with an AUC of 77.12 percent at a significance level of 5%.

Parity, Period of calving, Repeat breeding, ROP, Dystocia, Lameness and Udder wound were found to have significant effect on extremely prolong lactation legth with AUC of 80.17%, Parity, Period of calving, Repeat breeding and Pre-mature birth were found to have an impact on prolong lactation length. area under the curve is 68.48%.

With an AUC of 80.17 percent, Parity, Period of calving, Repeat breeding, ROP, Dystocia, Lameness, and Udder wound were found to have a significant effect on extremely prolong lactation length. Parity, Period of calving, Repeat breeding, ROP, Dystocia, Lameness, and Udder wound were found to have a significant effect on extremely prolong lactation length. The area under the curve is 68.48%.

All factors corresponding to lactation records on Murrah buffaloes were evaluated concurrently as fixed effects and using sire and animal within sire as random variables in a mixed model using Proc Mixed in SAS software version 9.3. Parity, Calving period, Month of calving, Repeat breeding, Abortion, Stillbirth, Retention of placenta and frequency of Prolapse, Lameness, Udder swelling, and

Vulva wound all showed a significant effect on lactation length at the 5% level of significance when analysed with a mixed model. Incidence of Repeat breeding, duration of Prolapse, Lameness and Pyometra were found to cause significant deviation of lactation length.

When the effect of previous lactation length and current lactation length were assessed after adjusting the traits for fixed effect, lactation yield, 305-milk yield, dry period and calving interval of the current lactation cycle were significantly affected at the 5% level of significance by current lactation length. It was also observed that the previous lactation length had a significant impact on weight at calving, lactation milk yield, 305 lactation milk yield, peak yield, and the service period of the next lactation cycle. The least squares mean of different lactation classes of current lactation cycle and next lactation cycle was estimated and animals showing extremely prolong lactation length had the highest least squares mean in both the lactation cycle.

Lactation length was estimated to have a heritability of 0.111±0.021 in standardised data, but only 0.053±0.018 in raw data. Lactation milk yield was determined to have a heritability of 0.314±0.095 in standardised data and 0.161±0.044 in raw data. In standardised data, the estimated heritability for 305-day milk yield was 0.222±0.052, but in raw data, it was assessed to be 0.361±0.09. In standardised data, peak yield heritability was calculated to be 0.204±0.038, while in raw data, it was found to be 0.151±0.039.

For Average fat percentage, heritability was moderate for standardised data, with a value of 0.415±0.061, and low for raw data, with a value of 0.293± 0.067. The service period had a heritability of 0.128±0.009 in standardised data, but a heritability of 0.099± 0.073 in raw data. In both standardised and raw data, the estimated heritability for conception rate was 0.081±0.026 for standardised data and 0.061 ± 0.045 for raw data, respectively.

In standardised data, lactation length had a significant ($P<0.01$) and high positive genetic correlation with lactation milk yield (0.769±0.058), 305-day milk yield (0.985±0.015), peak yield (0.529±0.077), and a moderate correlation with average fat percentage (0.354±0.085), whereas conception rate had a negative genetic correlation (-0.607±0.072) with lactation length. In addition, raw data revealed a significant ($P\leq0.01$) and positive genetic correlation between lactation length and service period (0.212±0.07).

Lactation length was found to have a significant ($P \leq 0.01$) phenotypic correlation with lactation milk yield and 305-day milk production in standardised data, with a positive and high correlation between lactation length and lactation milk yield (0.761±0.021) and 305-day milk yield (0.587±0.027). Lactation length also had a phenotypic correlation ($P<0.01$) with lactation yield (0.837±0.015), 305-day milk yield (0.714±0.020), peak yield (0.369±0.026), and service period (0.210±0.031) in raw data.

Using the spearman rank correlation approach in SAS software version 9.3, the effect of data exclusion or normalization on sire ranking was investigated. The correlation was estimated using the breeding values of the sire in both sets of data. Lactation length, lactation milk yield, 305-day milk yield, and peak yield all showed a significant but low correlation. The low correlation suggests that there is a significant discrepancy between the two sets of data, and that there will be significant differences in the outcomes if the two sets of data are used to rank sires. As a result, standardization of daughters' records can have a significant impact on sire breeding value estimation.

Conclusion

1. Lactation length has a considerable impact on the majority of essential production and reproductive parameters in Murrah buffaloes, demonstrating its relevance.
2. According to the findings of the current study, nearly one-fourth of the Murrah herd's lactation length deviated from normal while nearly one tenths showed excessive deviation (<126 days or >477 days).
3. From the degree of variation, it can be stated that prolong lactation lengths are more likely in Murrah buffaloes than short lactation length.
4. Abortion, stillbirth, prolapse, and udder swelling have all been identified as potential risk factors for short lactation length, whereas repeat breeding, ROP, Dystokia, Lameness, Udder wound, and pre-mature birth have all been proven to have a significant effect on prolonging lactation length. The significant risk factors identified are rare and cannot be eradicated clinically, indicating that good clinical care was given in the farm.

5. When compared to raw data, the estimation of genetic parameters improved with reduced standard errors in standardised data and thus, standardization of the data is recommended for calculation of genetic parameters.
6. The sire ranking based on breeding values revealed a significant difference between the two types of data, leading to the conclusion that sire breeding value assessment and ranking in unfiltered data should be preferred or atleast bulls must be screened for incidences of abnormal lactations and abnormal calving among daughters.

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