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Modelling the Effect of Mastitis on Milk Yield in Dairy Cows using Covariance Structures Fitted to Repeated Measures

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ABSTRACT

The objective of the present study was to study the effect of mastitis on milk yield in dairy cows by accounting the correlations among repeated records on monthly milk yield. The data were collected from monthly milk yield records of 482 dairy cows maintained at three Military Dairy Farms at Agra, Bareilly and Lucknow of Uttar Pradesh (India) for the period from 2011 to 2013. The overall prevalence of mastitis during study period was observed as 24.69%. Mixed modelling using four covariance structures (simple, compound symmetry, autoregressive and unstructured) was used to estimate effect of mastitis on milk yield by adjusting the effects of breed, mastitis, age, calving season, farm, month in lactation and random effects of each cow. On the basis of goodness fit criteria, unstructured covariance structure showed reliable results and estimated 36.76 kg losses due to mastitis in monthly milk yield in dairy cows.

Key words: Covariance structure, Dairy cow, Mastitis, Milk yield.

INTRODUCTION

Mastitis is defined as an inflammatory reaction of the mammary gland. It is of considerable interest because of its high incidence and the extensive costs associated with the disease (Singh, 2009; Bardhan, 2013). Mastitis is associated with yield loss at the time of diagnosis and more importantly, yield loss often persists throughout lactation (Houben *et al.* 1993; Rajala-Schultz *et al.*1999; Wilson *et al.* 2004). In India, economic losses due to mastitis are estimated at 3156 crores annually (Varshney and Naresh, 2004).

Repeated measures is defined as multiple responses of a trait on the same animal over time such as monthly milk yield records of dairy cows. These repeated measures on milk yield may be correlated in time but often considered as independent and hence, correlation between them is ignored. This can lead to inappropriate statistical inference about point of interest (Wilson *et al.* 2004). Therefore, it is utmost essential to account for these correlations to estimate the effects of factors on health outcomes with high precision and to investigate the patterns of variability influencing disease distribution in time and space, which can provide new insights into disease association (McDermott *et al.* 1994). The mixed model procedure have greater flexibility in modeling covariance structure for repeated measures data and adequately accounts for the within-subject time dependent correlations (Littell *et al.* 1998). Both the choice of covariance structure and the estimation method are important to provide valid results (Mc Dermott *et al.* 1997; Gröhn *et al.* 1999).

Therefore, the aim of the present study was to study the effect of mastitis on milk yield in dairy cows by using mixed modelling of the association among repeated records on monthly milk yield under four different covariance structures.

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MATERIALS AND METHODS

The data for the present study were compiled from monthly milk yield records of 482 lactating crossbred and frieswal cattle from history-cum-pedigree sheets, daily milk recording registers and disease registers maintained at three Military Dairy Farms at Agra, Bareilly and Lucknow of Uttar Pradesh (India) for the period from 2011 to 2013. The data on milk yield of incomplete lactation were not included in study. Only lactations which complete for eight months were selected.

The data were compiled and classified according to various factors such as farm (3 levels), breed (2 levels), calving season (3 levels) and parity (5 levels). Two breeds were considered as crossbred (3/8, 5/8, 3/4, 7/8 and 15/16 of Holstein Friesian and remaining inheritance of other indigenous cows) and Frieswal (62.5% Holstein Friesian and 37.5% Sahiwal inheritance). The calving season was classified as winter (November- February), Summer (March-June) and rainy (July-October). Age of the cows was recorded in years. Monthly milk yield data were available up to 8 months in most of cows, so we have considered

only 8 time points in the study. The monthly milk yield data for 9th and 10th months were omitted from the analysis to provide balanced data for studying covariance structure of lactation curve.

The mixed model procedure was used to study the effect of mastitis and other factors on monthly milk yield. In the mixed model procedure monthly milk yield up to 8 time points were taken as dependent variable whereas factors such as farm, mastitis, breed, parity and calving season were taken as fixed effects and individual cattle within mastitis group were taken as random effect. Age was taken as covariate in the model.

The mixed model methodology for repeated measures data was performed using four covariance structures *viz*. simple, compound, autoregressive (1) and unstructured (Grohn *et al.* (1999). Covariance structures were compared using goodness of fit criteria *viz.,* - 2 times the REML log likelihood (-2 R Log L), AIC (Akaike information criterion, Akaike, 1974) and SBC (Schwartz's Bayesian Criterion, Schwartz, 1978). The smallest value of information criteria indicates a better model fit to the data. Statistical analysis was carried out using proc MIXED procedure in SAS software (Littell *et al.*1998).

RESULTS AND DISCUSSION

The prevalence of mastitis and mean monthly milk yield (kg) for lactating cows maintained at three farms are given in Table 1. The overall prevalence of mastitis at three farms was 24.69%. The maximum prevalence was observed at Bareilly farm (27.59%) followed by Lucknow farm (23.36%) and Agra farm (22.81%). The findings were in similar line to those reported by Singh *et al.* (2014). The prevalence of clinical mastitis in crossbred cows in India ranges between 5% and 37% (Bangar *et al.*, 2016). Contrary to this finding, lower estimates were reported by De and Mukharjee (2009) and Sinha *et al.* (2014). Chi-square analysis showed that there was no significant ($p>0.05$) association for prevalence of mastitis at three farms.

The simple structure showed homogenous variance (13305) among time points without accounting correlations between repeated measures. The estimates of variance and covariance between different time points of lactation under compound symmetry structure were 13489.00 and 9336.64 respectively. The estimate of correlation between different time points of lactation was found to be 0.69. The estimate of variance due to AR (1) structure was observed as 13049. The correlation between any two consecutive time points was 0.84, which decreased as gap between time points increased, with minimum correlation (0.30) between 1st and 8th time point. The unstructured covariance matrix has minimum variance (11206) for first time point among all four covariance structure. However, the covariance and correlation pattern was observed decreasing as the length of time interval increases.

The parameter estimates of effects of mastitis and other variables on monthly milk yield using four covariance structure is presented in Table 2 and the results indicated that the mastitis causes huge economic loss in dairy cows. While adjusting to other factors such as breed, age, parity, season, farm and month of lactation, it was observed that estimated loss in monthly milk yield due to mastitis were 37.87, 37.99, 35.97 and 36.76 kg under simple, CS, AR (1) and unstructured covariance structure. The simple structure fails to recognize variation between cattle, this result in excessively large F values for breed, age and parity and therefore, this leads to false significance of these factors. But other structures *viz.,* CS, AR (1) and unstructured structure did not show significant effect for these factors. Among other fixed factors, calving season, farms and time points were found significant ($p<0.01$) for all covariance structures.

Among all these models, the unstructured covariance had smallest value of -2 R Log L, AIC and SBC. The AR (1) structure, however, had nearly as smaller value of AIC and BIC as unstructured covariance. These finding was in accordance with reports of Grohn *et al.* (1999). Both of these structures fit better than simple and CS structure. Based on goodness of fit measures, it was concluded that unstructured covariance structure was best for modeling of the effect of mastitis on monthly milk yield of dairy cows. These findings are in agreement with reports of Akbas (2002) and Shukla

Table 1: Prevalence of mastitis and mean (SE) monthly milk yield at three farms.

Month	Agra farm	Bareilly farm	Lucknow farm	Total
Observations	171	174	137	482
Affected cows	39	48	32	119
Mastitis %	22.81	27.59	23.36	24.69
Mean milk yield (kg)				
Month 1	326.94 ± 8.89	302.39 ± 7.47	400.18 ± 10.49	338.90 ± 5.42
Month 2	434.51 ± 13.74	375.36 ± 9.67	475.53 ± 11.98	424.82 ± 7.12
Month 3	423.57 ± 11.65	367.51 ± 9.65	471.73 ± 11.52	417.02 ± 6.59
Month 4	405.14 ± 11.28	348.01 ± 8.93	451.93 ± 9.98	397.82 ± 6.16
Month 5	391.60 ± 11.43	334.44 ± 8.28	427.41 ± 9.77	381.14 ± 5.99
Month 6	367.59 ± 11.00	317.06 ± 8.32	398.89 ± 8.24	358.25 ± 5.65
Month 7	334.02 ± 10.93	300.33 ± 7.97	365.12 ± 8.09	330.69 ± 5.46
Month 8	289.51 ± 11.24	282.77 ± 7.70	336.81 ± 8.05	300.46 ± 5.46

Table 2: Parameter estimates of the effect of mastitis on repeated monthly milk records in cows under four covariance structures, adjusted for breed, age, parity, farm, calving season and month of milk.

Effect	Covariance structures			
	Simple	CS	AR (1)	Unstructured
Intercept	362.35**	362.81**	350.63**	365.75**
Mastitis				
Yes	-37.87**	-37.99**	-35.97**	-36.76**
No	Ref			
Breed				
Crossbred	13.17*	13.03	7.47	2.57
Frieswal	Ref			
Age	5.73*	5.60	5.52	2.47
Parity				
1	-45.37**	-45.77	-29.14	-31.55
2	22.31*	22.04	26.21	17.58
3	36.89**	36.92	37.6	31.12
4	37.58**	37.6	33.13	25.77
≥ 5	Ref			
Calving season				
Summer	-69.57**	-69.78**	-54.40**	-46.40**
Rainy	-68.86**	-69.05**	-58.63**	-39.84**
Winter	Ref			
Farm				
AGC	-53.84**	-53.43**	-59.83**	-64.13**
BLY	-82.75**	-82.49**	-75.74**	-75.30**
LKO	Ref			
Month of milk				
1	38.49**	38.81**	40.04**	40.25**
2	124.42**	124.73**	125.96**	126.17**
3	116.62**	116.93**	118.17**	118.37**
4	97.42**	97.73**	98.96**	99.17**
5	80.74**	81.05**	82.29**	82.49**
6	57.85**	58.16**	59.39**	59.60**
7	30.41**	30.85**	32.19**	32.41**
8	Ref			
Goodness of fit				
-2 log L	47322.5	44248.6	43084.3	42488.8
AIC	47324.5	44252.6	43088.3	42560.8
SBC	47328.7	44260.9	43096.6	42711.2

CS: Compound symmetry; AR(1): Auto-regressive of first order; Log L: Log likelihood AIC: Akaike information criterion; SBC: Schwartz's Bayesian Criterion; Ref:Reference category, *(p<0.05), ** (p<0.01).

and Kumar (2012). Contrary to this finding, Littell *et al.* (2000) found that autoregressive with random effect is the best choice of covariance structure. Also, Grohn *et al.* (1999) and Wilson *et al.* (2004) preferred first order autoregressive structure over unstructured covariance structure to study the effect of disease on milk yield in dairy cows.

CONCLUSION

Mixed modelling using four covariance structures was done to estimate the effect of mastitis on milk yield by accounting the correlations between repeated measure data of monthly milk yield in dairy cows. The simple covariance showed false significance of some variables, however, by accounting the correlation in varied degree, CS, AR(1) and Unstructured covariance structure showed reliable results. On the basis of goodness fit measures, it was concluded that unstructured covariance structure was found to more appropriate method for better fitting of the repeated measures data and it was estimated that the mastitis caused 36.76 kg losses in monthly milk yield in dairy cows.

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