SHORT COMMUNICATION

A longitudinal study on the impact of species and age of animals on milk production in dairy animals

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Abstract: A longitudinal study was conducted to assess the impact of species and age of animals on milk production in dairy animals. The longitudinal data on milk yield of cattle and buffaloes have been recorded fortnightly interval up to 300 days for the period 2005 to 2014 from the dairy farm of Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly, Uttar Pradesh. From the study, we found that the base line milk yield was significantly (p value<.0001) higher in cattle than buffaloes. The change in milk yield decreases with time and this decrement was more in buffaloes than cattle. After adjusting for baseline age, on average cattle baseline milk yield was about 1.05 units more than buffaloes and after adjusting for species, one year increase in age corresponds to 0.102 unit increases in baseline milk yield. Cattle milk yield change rate was about 0.0009 units greater than buffaloes after adjusting for baseline age and one year increase in age corresponds to 0.0012 units less in milk yield change rate after adjusting for species.

Keywords: Generalized estimating equations, Linear mixed model, Model, Random effect model, Significant

The age of the lactating animal has important effect on the productive capacity of the animal. The effects of age differ from species to species and breed to breed. As the age of the animal increases, its body functions such as physiological and metabolic activities also increase up to a certain age (mature age) and then there is decline in these functions. For example, in terms of milk production, the productive capacity of the animal increases until body maturity is reached, and there after it decreases with advancing age. Age of the animal is an important factor which affects the mammary gland activity and rumen functions, which in turn affect the yield and composition of milk. For better understanding of the impact of species and age of animals on milk production in dairy animals, this work has been planned.

In the present study, the longitudinal data on milk yield (continuous data) of cattle and buffaloes have been recorded fortnightly interval up to 300 days for the period 2005 to 2014 from the dairy farm of Indian Veterinary Research Institute (IVRI), Izatnagar, Bareilly, Uttar Pradesh. A total of 180 dairy animals (Cattle and Buffaloes) have been recorded for the study.

The analysis of continuous longitudinal data has been undertaken by using two stage model, linear mixed model and generalized estimating equations (GEE) models (Edwards, 1985 and Diggle et.al., 1994). The models were applied in the analysis of continuous longitudinal data on milk yield. The two stage model was fitted by using Proc t test and Proc reg. Linear mixed model and Generalized Estimating Equations (GEE) was performed by using the Proc mixed procedures in SAS 9.3 (Zeger et al. 1988). The parameters of interest were species and age of the animal.

The model structure were

a) Two stage model: We examined the effect of age and species on intercept (b₀) by using the following model

\[ \hat{b}_0 = \alpha_0 + \alpha_{species} + \alpha_{age} + \varepsilon_0 \]  \hspace{1cm} (1.1)

and the effect of species and age on slope (b₁) by using the following model
\[ \hat{b}_1 = \beta_0 + \beta_1 \text{species} + \beta_2 \text{age} + \epsilon_1 \quad \text{................. (1.2)} \]

Model for true baseline response \(b_0\): The model for species and age for baseline response is given below:

\[ \hat{b}_0 = \alpha_0 + \alpha_i \text{species} + \alpha_i \text{age} + \epsilon_0 \quad \text{..................... (1.3)} \]

Model for change rate of the true baseline response \(b_1\): The model for species and age for change rate of true baseline response is given below:

\[ \hat{b}_1 = \beta_0 + \beta_i \text{species} + \beta_2 \text{age} + \epsilon_1 \quad \text{................. (1.4)} \]

b) Linear mixed model: A linear mixed model is an extension of a linear regression model to model longitudinal (correlated) data.

\[ y = \alpha + x\beta + \epsilon \quad \text{............... (2.1)} \]

Change in the milk yield associated with species and age

\[ b_{10} = \beta_0 + \text{species}_i \beta_0 \text{species} + \text{age}_i \beta_0 \text{age} + a_i \quad \text{...... (2.2)} \]

\[ b_{11} = \beta_1 + \text{species}_i \beta_1 \text{species} + \text{age}_i \beta_1 \text{age} + a_i \quad \text{...... (2.3)} \]

The \(\beta_0 \text{species}\), \(\beta_0 \text{age}\) are the species effect and the age effect on the baseline milk yield level. Similarly \(\beta_1 \text{species}\), \(\beta_1 \text{age}\) are the species effect and age effect on the change rate of the true milk yield level.

Substituting the above expression into model

\[ y_{ij} = b_{10} + b_{11}t_{ij} + \epsilon_{ij} \quad \text{....................... (2.4)} \]

We get

\[ y_{ij} = \beta_0 + \text{species}_i \beta_0 \text{species} + \text{age}_i \beta_0 \text{age} + \beta_1 t_{ij} + \text{species}_i \beta_1 \text{species} + \text{age}_i \beta_1 \text{age} + a_i + a_i t_{ij} + \epsilon_{ij} \quad \text{..... (2.5)} \]

Where \(y_{ij}\) is the \(j^{th}\) milk yield level measurement from subject \(i\), \(t_{ij}\) is time from the beginning of the study (or baseline) and \(b_{10}\) and \(b_{11}\) are random variables. \(\epsilon_{ij}\) are independent errors distributed as \(N(0, \sigma^2)\).

Generalized Estimating Equations (GEE): When the variation pattern in data is so high that we cannot use the random effect model then in that case we can use the model to estimate the fixed effects (\(\beta's\)) and use GEE approach to calculate the standard errors for the fixed effect estimates. These \(SE\) estimates will be valid regardless of the validity of the random effects structure. So these \(SE\) estimates are robust.

\[ y_{ij} = \beta_0 + \beta_1 t_{ij} + \beta_2 \text{species}_i \beta_0 \text{species} + \beta_1 \text{age}_i \beta_1 \text{age} + b_{10} + b_{11}t_{ij} + \epsilon_{ij} \quad \text{........ (3.1)} \]

The estimated value of \(\hat{b}_0\) for cattle was 8.8910 and for buffaloes 7.9290 means the base line milk yield was more in cattle than buffaloes, and this difference was highly significant (\(p\) value < .0001). The estimated value of \(\hat{b}_1\) for cattle was -0.0131 and for buffaloes -0.0133 means the change in milk yield decreases with time and this decrement was more in buffaloes than cattle. There is no significant difference (\(p\) value =0.6302) between cattle and buffaloes with respect to change rate in milk yield with time. The estimated value of variance \(\hat{S}^2_{b_0}\) for baseline milk yield was 16.926 for cattle which was more than variance of buffaloes (3.862) and there was highly significant difference (\(p\) value <0.0001) between the variance of cattle and buffaloes. The estimated value of variance \(\hat{S}^2_{b_1}\) for change rate in milk yield with time was 0.00017 for cattle which was more than variance of buffaloes (0.0001) and there was highly significant difference (\(p\) value <0.0001) between the variance of cattle and buffaloes. The estimated value of intercept \(\hat{\alpha}_0\) for this model was 9.4303 with standard error 0.1952. The estimated value of \(\hat{\alpha}_1\) for species variable was -1.0566 with standard error 0.1237 that indicates that after adjusting for baseline age, on average cattle

| Model       | AIC    | BIC    |
|-------------|--------|--------|
| Model (2.1) | 17053.8| 17066.6|
| Model (2.5) | 17054.4| 17067.2|
| Model (3.1) | 17054.4| 17067.2|
baseline milk yield was about 1.05 units more than buffaloes. The estimated value of $\hat{\alpha}_2$ for age variable was 0.1023 with standard error 0.0221 that indicates that after adjusting for species, one year increase in age corresponds to 0.102 unit increases in baseline milk yield. The estimated value of intercept $\hat{\beta}_0$ for this model was -0.0078 with standard error 0.0006. The estimated value of $\hat{\beta}_1$ for species variable was 0.0009 with standard error 0.0004 that indicated that after adjusting for baseline age, cattle milk yield change rate is about 0.0009 units greater than buffaloes. The estimated value of $\hat{\beta}_2$ for age variable was -0.0012 with standard error 0.00007 that indicated that after adjusting for species, one year increase in age corresponds to 0.0012 units less in milk yield change rate.

Tekerli et al. (2000) reported that the cattle in 1st lactation produced lower milk yield but they were more persistence in milk production with respect to older parity animals. Madani et al. (2011) reported that milk yield in early calving group produced 20% and 24% less milk yield during second lactation as compared respectively to medium and late maturing group. Tekerli et al. (2000) concluded that primiparous cow produce lower milk yield but they are more persistence in milk production with respect to older parity animals. Rekik et al. (2003) concluded that the ascending phase of lactation is not affected by parity and calving season; Persistency of milk production and peak yield varies significantly with variable which affects milk production; In contrast to 1st lactation, 3rd lactation had the highest peak milk yield & total milk yield. Kumar et al. (2012) concluded that genetic group and lactation order had significant effect on lactation length, total milk yield and peak yield.

The choice of model, especially the fixed terms, depends on objective of the study. However, we can use Akaike information criterion (AIC) or Bayesian information criterion (BIC) to determine the random effects and the error structure. If we want a model with the most prediction power, we can consider a complicated model with AIC or BIC as a guide for model selection. Here it seems that model (3.1) is the winner among different models if we are looking for a model with the most prediction power (Table 1)

Conclusions

The present longitudinal study generated information about the impact of species and age of animals on milk production in dairy animals. The analysis involved determining the change in milk yield with time in dairy animals and to assess the milk yield change with respect to species and age of animal. The base line milk yield was more in cattle than buffaloes, and this difference was highly significant (p value<.0001). The change in milk yield decreases with time and this decrement was more in buffaloes than cattle.

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