Sire evaluation models for estimating breeding values of Mehsana buffaloes

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Received: 30 August 2018; Accepted: 24 September 2018

ABSTRACT

First lactation data on 7,782 Mehsana buffaloes sired by 184 sires maintained at Dudhsagar Research and Development Association, Dudhsagar Dairy, Mehsana over a period of 24 years (1989–2012) were used to estimate least-squares means (LSM) and breeding value of the first lactation fat yield (FLFY) and average fat percentage (AFP) using univariate and bivariate models with the help of WOMBAT software. The effectiveness of different sire evaluation models using FFLY and AFP were compared on the basis of error variance, coefficient of determination (CV%), R²-value, AIC, BIC and Spearman’s rank correlation. The average estimate of FFLY and AFP was 135.04±0.57 kg and 7.11±0.11% in Mehsana buffaloes. These estimates were significantly affected by period and season of calving, and age at first calving group. The average expected breeding value of Mehsana buffalo bulls for FFLY and AFP were 133.24 kg and 7.14% using sire model (BLUP-SM), 135.71 kg and 7.22% using univariate animal model (BLUP-U-AM) and 133.23 kg and 7.14% from bivariate animal model (BLUP-B-AM), respectively for FFLY and AFP. The spearman’s rank correlation indicated similarity of rankings by BLUP-U-AM and BLUP-B-AM. Animal model had a wider range of breeding values indicating the greater differentiating ability of the model. Based on error variance, AIC, BIC, R² and CV; animal model was found to be superior in comparison to sire model.

Key words: Animal model, Bivariate, Breeding value, Sire model, Univariate

Livestock is an integral component of agriculture and dairy sector plays a vital role in agricultural economy with an annual growth rate of 4–5%. Since 1998, India continues to hold the number one position among milk producing nations of the world. The total quantum of milk produced in India during 2016–17 was 165.4 million tonnes (NDDB 2017). India ranks first in the world in terms of buffalo population, constituting over 57.53% of the total world buffalo population (Iºik and Gül 2016). Compared with cow’s milk, buffalo’s milk has a higher % fat percentage. Buffaloes contribute more than 49% of total milk production of India (DAHD 2017). Milk fat plays a significant role in the nutritive value and physical properties of milk and milk products. The most distinctive role which milk fat plays in dairy products concerns flavour (Kumar et al. 2016). At present, milk pricing system is also based on the percentage of fat in milk. Therefore, higher milk fat yield fetches better economic returns.

The ultimate aim of animal breeders is to select the genetically superior bulls for genetic improvement in the productive as well as reproductive performances of animal population. The selection of females (dams) has limited scope due to insufficient number of replacement stock. So, the selection of superior sires is of utmost importance and is key step in any breed improvement programme. An early and accurate judgment of sire’s breeding value is crucial for long term genetic progress in the population. In majority of instances in India, breeding value of sires is estimated mainly using single trait (Verma et al. 2017, Prajapati et al. 2017). In some cases, breeding value has been estimated after incorporating more than one trait (Divya et al. 2014), but evaluation of sires in buffaloes, for milk fat has not been reported so far. The optimum method for evaluation of animal is multiple trait analysis, which takes into account the phenotypic and genetic associations between the traits. Univariate model produces simple correlations, whereas a multivariate model utilises all the inter-correlations among traits, gives more accurate estimates and precise predictions. In view of these facts, the present study was undertaken to predict breeding values of Mehsana buffalo bulls using first lactation fat yield and average fat percentage.

MATERIALS AND METHODS

The first lactation records of 8,222 Mehsana buffaloes,
spread over a period of 24 years from 1989 to 2012, maintained at Dudhsagar Research and Development Association (DURDA), Dudhsagar Dairy, Mehsana were collected. The data from same set of animals were used for both univariate and bivariate analysis. Sires having at least 10 progenies were considered in present study. Therefore, the first lactation records of 7,782 Mehsana buffaloes sired by 184 sires on FLFY (first lactation fat yield) and AFP (average fat percentage) were used for the analysis.

The data were classified into different subclasses based on season as well as period of calving and different age groups based on age at first calving for FLFY and AFP. The year was classified into 2 seasons (Breeding season-1, January to June and Breeding season-2, July to December), periods of calving was classified into 4 groups (Period 1 (P1) (1989 to 1994), Period 2 (P2) (1995 to 2000), Period 3 (P3) (2001 to 2006) and Period 4 (P4) (2007 to 2012), and age at first calving was classified (using Sturges’ rule) into 3 groups AFC1 (677 to 1100), AFC2 (1101 to 1680) and AFC3 (1681 to 2555).

To estimate the effect of non-genetic factors on FLFY and AFP, mixed model analysis of data was employed using least-squares maximum likelihood programme (Harvey 1990). The statistical model used to estimate the effect of non-genetic factors was:

\[ Y_{ijkl} = \mu + A_i + B_j + C_k + e_{ijkl} \]

where \( Y_{ijkl} \) observations; \( \mu \), population mean; \( A_i \), fixed effect of \( i^{th} \) period of calving; \( B_j \), fixed effect of \( j^{th} \) season of calving; \( C_k \), fixed effect of \( k^{th} \) age group of first calving; and \( e_{ijkl} \), random error, assumed to be normally and independently distributed with zero mean and constant variance, i.e. (NID, 0, \( \sigma^2 \)).

The difference of means between any two subclasses of period, season and age at first calving was tested for significance using Duncan’s Multiple Range Test (DMRT) as modified by Kramer (1957). The variance-covariance components were estimated by applying univariate and bivariate model as per REML method using WOMBAT software (Meyer 2007) for one and two traits analysis, respectively. The traits FLFY and AFP were analysed using univariate animal model for estimation of their corresponding variance-covariance components fitting REML method. Similarly, FLFY with AFP two trait combinations were analysed using bivariate animal model for estimation of their corresponding variance-covariance components fitting REML.

Three methods, viz. Best linear unbiased prediction sire model (BLUP-SM), Best linear unbiased prediction univariate animal model (BLUP-U-AM) and Best linear unbiased prediction bivariate animal model (BLUP-B-AM) were used for sire evaluation. The sire model (BLUP-SM), used to estimate the breeding values was:

\[ y_{ijk} = X_{bi} + Z_{aj} + c_{ijk} \]

where \( y_{ijk} \) observations; \( X \), incidence matrix for fixed effects with dimension (\( n \times p \)); \( Z \), incidence matrix for random sire effect with dimension (\( n \times q \)); \( b_i \), vector of fixed effects with dimension (\( p \times 1 \)); \( S_p \), vector of sire effect with dimension (\( q \times 1 \)) and \( e_{ijk} \), vector of random residual effects with dimension (\( n \times 1 \)).

The animal model (BLUP-U-AM) used for univariate analysis was:

\[ Y_{ijk} = X_{bi} + Z_{aj} + e_{ijk} \]

where, \( Y_{ijk} \), observation; \( b_i \), vector of observation of fixed effects; \( a_j \), vector of additive genetic effect; \( X \), design matrix/incidence matrix of fixed effect; \( Z \), design matrix/incidence matrix of random effect and \( e_{ijk} \), residual errors.

The Bivariate animal model (BLUP-B-AM) used to estimate the breeding value was:

\[ \begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{pmatrix} = \begin{pmatrix} x_1 \\ 0 \\ x_2 \\ 0 \\ x_2 \end{pmatrix} \begin{pmatrix} b_1 \\ 0 \\ b_2 \\ 0 \\ b_2 \end{pmatrix} + \begin{pmatrix} z_1 \\ 0 \\ z_2 \\ 0 \\ z_2 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_2 \\ a_2 \\ a_2 \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ e_2 \\ e_2 \\ e_2 \end{pmatrix} \]

The effectiveness of different sire evaluation models using FLFY and AFP were compared on the basis of efficiency (error variance), stability (coefficient of variation, CV), accuracy (coefficient of determination, \( R^2 \)), Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Sires were ranked on the basis of breeding values estimated by all three types of models used. Efficiency of BLUP-U-AM, BLUP-U-AM and bivariate animal model (BLUP-B-AM) was adjudged on the basis of Spearman’s rank correlation (Spearman 1904) between the rankings of bulls by all these three models.

RESULTS AND DISCUSSION

Least-squares means and factors affecting FLFY and AFP: The least-squares means for FLFY and AFP were 135.04±0.57 kg and 7.11±0.11% respectively. The estimates of both these traits were in agreement with those reported by Yadav et al. (2013) in Murrah buffaloes. However, contradictory to present finding lower estimate of FLFY was reported by Kumar et al. (2016) in Murrah buffaloes. The present estimate of AFP was lower than those obtained in Mehsana and Banni buffaloes (Annual Progress Report, 2015) and Murrah buffaloes (Verma et al. 2017).

Period, season and calving age group were found to had significant effect on FLFY (\( P<0.01 \)) (Table 1). Season of calving was contributing maximum to the total variance present in these two traits. No such report on Mehsana buffaloes could be found in literature however, similar findings were reported by Kumar et al. (2016) and Verma et al. (2017), respectively, in Murrah buffaloes. The results suggested that first calving at proper mature age might have provided healthy body condition that resulted in higher fat yield as well as fat percentage. This was in accordance with those reported by El-Bramony (2017) in Egyptian buffaloes. Seasonal and periodical differences in temperature, humidity and rainfall, affect the availability and varieties of feed and fodder, upon which the fat yield in buffaloes depends. The current results confirmed that variation in year-seasons and herds affected milk fat related traits in Mehsana buffaloes.

Breeding value estimates for FLFY and AFP: The average breeding value of 184 Mehsana sires evaluated on
The estimated breeding values of Mehsana buffalo bulls with FLFY and AFP respectively. The top ranking sire having the highest estimated breeding value of 176.22 kg had genetic superiority 29.85% and 7.94% had 9.97% genetic superiority over the overall average for FLFY and AFP. The top ranking sire having the highest estimated breeding value of 165.78 kg had genetic superiority 24.4% and 7.81%; had 9.33% genetic superiority 24.8% and 1362) 7.09±0.18 a (9.3, 1362)

** Season **
1 138.94±0.93 a (24.8, 1362) 7.09±0.18 a (9.3, 1362)
2 131.13±0.49 b (24.7, 6420) 7.14±0.97 b (9.0, 6420)

** AFC Group **
1 137.91±1.00 a (24.2, 1230) 7.26±0.19 a (9.4, 1230)
2 136.75±0.55 a (24.9, 5344) 7.12±0.10 b (8.9, 5344)
3 130.45±0.99 b (25.0, 1208) 6.97±0.19 b (8.9, 1208)

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** Table 1. Least squares means±SE and coefficient of variations for FLFY and AFP **

| Trait          | FLFY (kg)  | AFP (%)   |
|----------------|------------|-----------|
| ** μ **        | 135.04±0.57 (24.8, 7782) | 7.11±0.11 (9.0, 7782) |
| ** Period **   | 131.31±0.93 a (22.4, 1576) | 7.00±0.18 a (8.1, 1576) |
| ** 2 **       | 135.56±0.89 a (23.8, 1677) | 7.15±0.17 a (8.9, 1677) |
| ** 3 **       | 132.19±0.77 a (26.0, 2683) | 7.13±0.15 a (8.9, 2683) |
| ** 4 **       | 141.07±0.87 a (25.4, 1846) | 7.17±0.16 a (9.8, 1846) |

** Table 2. EBVs of FLFY and AFP from different models **

| Model          | Trait combination | Avg. EBV | Max. EBV | Min. EBV |
|----------------|-------------------|----------|----------|----------|
| BLUP-SM        | FLFY              | 133.24 kg | 140.99 kg | 130.34 kg |
|                | AFP               | 7.41%    | 7.42%    | 6.69%    |
| BLUP-U-AM      | FLFY              | 135.71 kg | 176.22 kg | 104.85 kg |
|                | AFP               | 7.22%    | 7.94%    | 6.10%    |
| BLUP-B-AM      | FLFY-AFP          | 133.23 kg | 165.78 kg | 101.67 kg |
|                | AFP-FLFY          | 7.14%    | 7.81%    | 6.19%    |

** Table 3. Spearman’s rank correlations between BV of FLFY and AFP estimated by different models **

| First lactation | Fat yield (FLFY) |
|-----------------|------------------|
| BLUP-SM         | 0.92**           |
| BLUP-U-AM       | 0.92**           |
| BLUP-B-AM       | 0.97**           |

** Highly significant at P ≥ 0.01. **

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** Table 3. Spearman’s rank correlations between BV of FLFY and AFP estimated by different models **

| First lactation | Fat yield (FLFY) |
|-----------------|------------------|
| BLUP-SM         | 0.92**           |
| BLUP-U-AM       | 0.92**           |
| BLUP-B-AM       | 0.97**           |

** Highly significant at P ≤ 0.01. **

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** Table 3. Spearman’s rank correlations between BV of FLFY and AFP estimated by different models **

| First lactation | Fat yield (FLFY) |
|-----------------|------------------|
| BLUP-SM         | 0.92**           |
| BLUP-U-AM       | 0.92**           |
| BLUP-B-AM       | 0.97**           |

** Highly significant at P ≤ 0.01. **
the traits were lower than the BLUP-SM but higher than BLUP-U-AM, indicating BLUP-U-AM as the most efficient model. Contrary to present finding, Dash et al. (2016) reported bivariate animal model as the most efficient, which may be due to the use of different trait combinations.

**Coefficient of determination:** The BLUP-B-AM method for FLFY had highest $R^2$ (91.84%) value, followed by BLUP-U-AM (41.04%) and BLUP-SM (7.00%). Similar to that, the BLUP-B-AM method for AFP had highest $R^2$ (91.84%) value followed by BLUP-U-AM (63.46%) and BLUP-SM (7.19%) model (Table 4). Therefore, the criterion of using $R^2$ again confirmed the superiority of BLUP-B-AM model. Higher $R^2$ value for AFP for BLUP-B-AM method followed by BLUP-SM and least squares method was observed by Chitra et al. (2017) in Murrah buffaloes. Bivariate animal models for genetic evaluation of bulls was recommended by Dash et al. (2016) for fertility and milk yield whereas, Mukherjee (2005) recommended multivariate animal model for the same. The $R^2$ of different bivariate animal models of sire evaluation were reasonably high and showed good variation. It may be concluded based on the criteria used for comparing the effectiveness of different methods that BLUP-B-AM model was more efficient and accurate compared to other two models, owing to highest $R^2$ value.

**Akaike Information Criterion and Bayesian Information Criterion:** The BLUP-U-AM model for FLFY had lowest AIC and BIC values followed by BLUP-B-AM and BLUP-U-SM. However, the difference between the AIC and BIC estimates of BLUP-U-AM and BLUP-B-AM were very low and hence both the models can be considered as equally fit. Similarly, BLUP-B-AM model for AFP had lowest AIC and BIC value followed by BLUP-U-AM and BLUP-SM (Table 4). The results of predicted EBVs indicated that the BLUP-U-AM is superior in comparison to BLUP-SM. Bivariate animal model (BLUP-B-AM), for trait combination of AFP with FLFY was equally good with the animal model. Similar to our finding, Dash (2014) also estimated lower AIC values for different traits in Karan-Fries cattle.

**Coefficient of variation (CV):** BLUP-U-AM and BLUP-B-AM had higher CV% than that of the BLUP-SM and appeared more stable method compared to others, for FLFY and AFP (Table 4). Similar to the present study, Dash (2014) in Karan-Fries cattle also reported BLUP-U-AM to be more stable.

The results indicated that bivariate as well as univariate animal model had greater ability for differentiating superior and inferior sires with respect to FLFY or AFP than univariate sire model. The inclusion of AFP along with FLFY does not much improve the differencing ability of bivariate animal model. Univariate animal model may be applied rather than univariate sire model for genetic evaluation of sires, on account of relatively higher efficiency (low error variance), higher accuracy (high $R^2$), higher stability (higher CV), lower Akaike Information Criterion (AIC) and lower Bayesian Information Criterion (BIC) in Mehsana buffaloes. Use of this model is, therefore, recommended for genetic evaluation of Mehsana buffalo bulls. Adequate variation in breeding values of FLFY and AFP (high CV%) appear to promise further improvement in production of these animals through continued progeny testing. The bivariate animal model of traits combination AFP-FLFY were found superior models on the basis of estimates of $R^2$ value, AIC and BIC values. The AFP-FLFY model was optimum for determination of effectiveness of models of sire evaluation.

**ACKNOWLEDGEMENTS**

The authors express their sincere gratitude to the Dean and Principal, College of Veterinary Science and Animal Husbandry for all possible cooperation and facilities for the successful completion of this study and Manager TI, Dudhsagar Research and Development Association, Dudhsagar Dairy, Mehsana for providing the data for research work.

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**Table 4. Estimation of coefficient of determination values, for effectiveness of different traits**

| Model                  | Trait combination | Error variance | $R^2$ (%) | AIC           | BIC           | CV (%) |
|------------------------|-------------------|----------------|-----------|---------------|---------------|--------|
| Sire model             | FLFY              | 7925430        | 7.00      | −30976.9      | −30983.9      | 3.47   |
|                        | AFP               | 2993.91        | 7.19      | −328.0        | −334.9        | 1.37   |
| Univariate animal model| FLFY              | 5023520        | 41.04     | −31026.8      | −31033.8      | 9.56   |
|                        | AFP               | 1176.72        | 63.46     | −348.06       | −355.02       | 3.87   |
| Bivariate animal model | FLFY-AFP          | 5742580        | 91.84     | −30851.5      | −30874.4      | 8.11   |
|                        | AFP-FLFY          | 1650.11        | 91.84     | −30851.5      | −30874.4      | 3.52   |
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