



Sire evaluation models for estimating breeding values of Mehsana buffaloes

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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 FLFY and AFP were compared on the basis of error variance, coefficient of determination (CV%), R^2 -value, AIC, BIC and Spearman's rank correlation. The average estimate of FLFY and AFP was 135.04 ± 0.57 kg and $7.11 \pm 0.11\%$ 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 FLFY 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 FLFY 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, R^2 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 (I^oik 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.

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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 utilised 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; μ , 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, σ^2).

The difference of means between any two subclasses of period, season and age at first calving group 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:

$$y_{ijk} = Xb_i + Zs_j + e_{ijk}$$

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_j , 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:

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} x_1 & 0 \\ 0 & x_2 \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix} + \begin{pmatrix} z_1 & 0 \\ 0 & z_2 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \end{pmatrix}$$

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-SM, 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 $7.11 \pm 0.11\%$ 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

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)
<i>Period</i>	**	**
1	131.31±0.93 ^a (22.4, 1576)	7.00±0.18 ^b (8.1, 1576)
2	135.56±0.89 ^b (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 ^c (25.4, 1846)	7.17±0.16 ^a (9.8, 1846)
<i>Season</i>	**	**
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)
<i>AFC Group</i>	**	**
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 ^c (8.9, 1208)

**Highly significant at $P \leq 0.01$.

the basis of single traits FLFY and AFP and combination of two traits, FLFY-AFP and AFP-FLFY estimated by BLUP-SM, BLUP-U-AM and BLUP-B-AM methods were 133.24 kg and 7.14%, 135.71 kg and 7.22% and 133.23 kg and 7.14%, respectively (Table 2). Among the 3 models used, the BLUP-U-AM method gave the maximum overall average breeding value for the Mehsana buffalo sires for FLFY and AFP. 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 respectively. Approximately 30% superiority of top ranking sires than the average sire of the herd is indicative of very good fat yielding potential of Mehsana buffalo bulls.

Similarly, in bivariate model, the highest and lowest breeding values for FLFY with AFP as co-variable and for AFP with FLFY co-variable were 165.78 and 101.67 kg as well as 7.81 and 6.19%, of top and bottom ranking sires, respectively. 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 over the overall average for FLFY and AFP, respectively. Limited study for estimation of breeding value of fat yield had been reported. However, lower estimate of breeding value of FLFY than the present estimate was obtained by Zutere (2008) in Latvian Boran cattle.

The estimated breeding values of Mehsana buffalo bulls in the present study by sire model, univariate animal and

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	146.99 kg	119.34 kg
	AFP	7.14%	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%

bivariate animal models for FLFY and AFP revealed substantial variation in estimates. Different methods employed in this study also indicated variation in percentage of sires having breeding values above or below the average breeding values of sires for a given trait and evaluation methods. The ranges of their breeding values also differed considerably among themselves. The substantial variation present in estimates of breeding value of these traits advocates the identification of top ranking sires and their subsequent use in the programme.

Spearman's rank correlations of univariate and bivariate models

The rank correlation estimates of FLFY and AFP indicated very strong and highly significant ($P < 0.01$) correlation between the univariate and bivariate rankings. It was observed that the rank correlations amongst EBVs by single-trait (BLUP-SM and BLUP-U-AM) methods were in the range of the, highest 0.95 (AFP) to the lowest 0.92 (FLFY), i.e. the ranking of sires by both BLUP-SM and BLUP-U-AM were having maximum similarity for AFP and least similarity for FLFY (Table 3). The rank correlation estimate for FLFY and AFP were 0.92 and 0.97 indicating very strong ($\geq 0.80-1.00$) and highly significant correlation between the univariate and bivariate rankings, when FLFY was included with AFP in bivariate animal model (Table 4). Similar high and significant correlations between bivariate and univariate model among production traits were also reported by Dash *et al.* (2016) in HF cross cattle. The rank correlation coefficients among breeding value of sires by different methods of sire evaluation showed a reasonably higher degree of agreement in the ranking of sires.

Within sire variance or error variance (efficiency): The error variances among various single-trait univariate methods of sire evaluation for FLFY and AFP under study revealed that the single-trait animal models (BLUP-U-AM) had lower error variance (Table 4). The BLUP-U-AM method for FLFY and AFP had lowest error variance (5023520 and 1176.72) followed by BLUP-SM (7925430 and 2993.91). The present finding of lower error variance with BLUP-U-AM is analogous with those reported by Chitra *et al.* (2017) and Sahoo *et al.* (2018) in Murrah buffaloes. However, estimates of error variance for both

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

First lactation	Fat yield (FLFY)		
	BLUP-SM	BLUP-U-AM	BLUP-B-AM
BLUP-SM	1	0.92**	-
BLUP-U-AM		1	0.92**
BLUP-B-AM			1
	Average fat percentage (AFP)		
BLUP-SM	1	0.95**	-
BLUP-U-AM		1	0.97**
BLUP-B-AM			1

**Highly significant at $P \leq 0.01$.

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

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 R² (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 R² (91.84%) value followed by BLUP-U-AM (63.46%) and BLUP-SM (7.19%) model (Table 4). Therefore, the criterion of using R² again confirmed the superiority of BLUP-B-AM model. Higher R² value for BLUP-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 R² 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 R² 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 method 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 R²), 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 R² value, AIC and BIC values. The AFP-FLFY model was optimum for determination of effectiveness of models of sire evaluation.

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