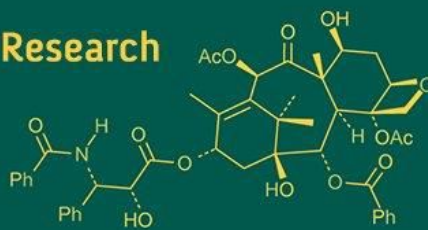


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Comparison of breeding value for test day milk yield and test day energy corrected milk yield in Mehsana buffaloes

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Abstract

A total of 32,123 first lactation test day milk yield (TDMY) records of 8,023 Mehsana buffalo sired by 118 sires from 2012 to 2019 for three districts of Gujarat state, were considered and analyzed in the present study to compare the ranking of sires for energy corrected milk yield (ECMY) and TDMY by the different models. The rank correlation of sires estimated breeding values (EBVs) between 305D milk yield (MY) and 305D ECMY for all sires, top 75%, top 50%, top 25%, top 10%, bottom 75%, bottom 50%, bottom 25% and bottom 10% were found highly significant ($p < 0.01$) for all traits except correlation was significant ($p < 0.05$) for top 10% bulls. The rank correlation of sires EBV between 305D MY and 305D ECMY with greater than or equal to 60% reliability, were found highly significant for all sires, top 75%, top 50%, bottom 75%, bottom 50% and bottom 25% whereas correlation was significant for top 25% and bottom 10% except 305D 4% fat corrected milk yield (FCMY) and 305D 6% FCMY while correlation was non-significant for top 10%, 305D 4% FCMY and 305D 6% FCMY of bottom 10% sire. This shows the huge changes in ranking of sires if selected based on 305D ECMY as compared to selected based on 305D MY in Mehsana buffalo. The rank correlation among sires with top rank for milk yield had significantly different rank for energy corrected milk yield. It indicates that selection for milk yield is likely to produce less energy efficient daughters for milk yield therefore it is recommended to select sires based on energy corrected milk yield in Mehsana buffalo.

Keywords: Energy corrected milk yield, breeding value, BLUP, RRM

Introduction

Rapid population growth in India has led to a significant rise in demand for milk and dairy products. Milk plays a critical role in addressing nutritional insecurity, especially in rural areas where livestock are a key source of food and income. Although India ranks first globally in milk production, the share of dietary energy from dairy is only 4.4%, compared to 14.0% in developed countries (FAO, 2013) ^[2]. The per capita dietary energy intake projected for 2030 is 2860 kcal/person/day in developing countries, compared to 3430 kcal/person/day in developed countries (FAO, 2012) ^[1, 3].

Milk composition varies by species and breed. While water is the major component, the nutritional value depends on fat, protein, SNF, and lactose. Emphasis on milk quantity over quality has negatively impacted both nutritional content and marketability. The energy value of milk can be estimated based on the concentrations of fat, protein, and lactose (Perrin, 1958) ^[4]. Although incorporating energy balance into breeding programs is ideal, direct measurement remains expensive and complex (Hüttmann *et al.*, 2009) ^[5].

Energy corrected milk yield accounts for fat and protein content, offering a more accurate reflection of nutritional value. In a largely vegetarian country like India, milk contributes an average of 134 kcal energy, 8 g protein, and 7.3 g fat per capita daily (FAOSTAT, 2012) ^[3]. Considering the potential of milk to mitigate bio-energy insecurity, an attempt was made to utilize energy corrected milk yield as a trait for evaluation of Mehsana buffalo which can aid in genetic improvement focused on energy output. Buffalo milk is more energy-dense than cow milk, with higher fat and protein content (FAO, 2013) ^[2]. It is also more efficient for dairy processing (Ménard *et al.*, 2010) ^[6].

Bulls with high milk-yielding daughters may not produce energy-efficient progeny, justifying the need to prioritize ECM or FCM over raw milk yield. This study explores that hypothesis.

Materials and Methods

Data

We analyzed a total of 40,200 data points of first-lactation test-day milk yield records of 3,877 buffaloes sired by 118 bulls, spread over a period of 8 years (2012-2019). The first-lactation test-day records of farmers' herds of Mehsana buffalo for test-day milk yield, test-day fat %, test-day protein %, and test-day SNF % for three districts of Gujarat State, viz., Mehsana, Patan, and Gandhinagar, under the field progeny testing project were collected from INAPH (Information Network for Animal Productivity & Health) developed by NDDDB.

The animals without sire information were eliminated from the study. Only first-lactation records were considered in the present study. The animal records from 5 to 330 days in milk (DIM), 22 to 109 months of age at first calving (AFC), 1 to 17 kg test-day milk yield, 4 to 12 fat %, 7 to 12.50 SNF %, 2 to 6 protein %, and a minimum of 1 and a maximum of up to 11 test-day milk records were retained; yield was converted into kg and outliers were removed. The animals spread over 103 villages of 14 tehsils belonging to 3 districts were considered. The minimum observations for an animal, HYMR (Herd × Year × Month of recording), YC (Year of calving), and YSC (Year of calving × Season of calving) were 3, 1, 1, and 1, respectively.

Consequently, out of 40,200 first lactation TDMY records of Mehsana buffalo 8,077 records were discarded. Thus, a total of around 20.09% records were discarded on account of all the above restrictions. Finally, 32,123 test day records of 487 daughters sired by 118 sires were used in data file for the present study.

First lactation test day energy corrected milk

The milk energy correction formulas of 4% FCM (4% Fat corrected milk), 6% FCM (6% Fat corrected milk), ECM1 (Energy corrected milk 1), ECM2 (Energy corrected milk 2), SCM (Solid corrected milk) and FPCM (Fat and protein corrected milk) used in present study are presented in Table 1.

Statistical Analysis

Heritability, variance and covariance components for test day milk yield (TDMY), test day fat yield (TDFY), test day SNF yield (TDSNFY) and test day protein yield (TDPY) were estimated using Average Information Restricted Maximum Likelihood (AIREML) algorithm using Legendre Polynomials to transform days in yield. A random regression test day (RRTD) model is used to estimate the parameters. Estimated variance and covariance components were used for estimation of breeding value using BLUP methodology for the univariate RRTD model.

Model used

$$y_{thijkl} = \text{Herd}_j + \text{Owner}_h + \text{HYMR}_i + \sum_{k=0}^{nf} \phi_{ktl} \beta_l + \sum_{k=0}^{nr} \phi_{ktl} u_{kl} + \sum_{k=0}^{nr} \phi_{ktl} p e_{kl} + e_{thijkl}$$

Where,

y_{thijkl} = the test day milk yield of k^{th} animal made on t^{th} days in milk (DIM)

Herd_j = herd as fixed effect with subclass j

Owner_h = owner as random effect with subclass h

HYMR_i = herd * year of milk recording * month of milk recording as random effect with subclass i

β_l = fixed regression coefficients

u_{kl} and $p e_{kl}$ = the l^{th} random regression for animal additive genetic and permanent environmental effects, respectively, for animal k

ϕ_{ktl} = the l^{th} Legendre polynomial for the test day record of animal k made on t^{th} day in milk

nf = the order of polynomials for DIM

nr = the order of polynomials for animal and p effects

e_{thijkl} = the random residual effect

The DIM was transformed using Legendre polynomials of 'n' order as described below. However, the second order of LPs were used in the present study.

The matrix ϕ is of order t (the number days in milk) by k (order of fit) with element $\phi_{ij} = \phi_j(\alpha_i)$ equals the j^{th} Legendre polynomial evaluated at the i^{th} standardized DIM. Consequently, α_i is the i^{th} DIM standardized to the interval for which the polynomials are defined.

In matrix notation, $\phi = M\Delta$, where M is the matrix containing the polynomials of the standardized DIM values and Δ is a matrix of order k containing the coefficients of Legendre polynomials. The elements of M can be calculated as $m_{ij} = (\alpha_i^{j-1})$, $i = 1, \dots, t$; $j = 1, \dots, k$.

Here, standardized DIM can be calculated after calculating the total milk yield from the known part of lactation length, the rest of the unknown lactation part up to 300 days lactation lengths were estimated by the prediction equations (Habib *et al.*, 2019) [12].

Legendre polynomials were calculated for matrix Δ . The j^{th} Legendre polynomial evaluated at DIM t ($P_j(t)$), can be evaluated by the formula given by Abramowitz and Stegun (1965) [13].

Sire Evaluation

Estimated variance and covariance components were used in breeding value estimation of breeding bulls using univariate Best Linear Unbiased Prediction (BLUP) model for test day records. The 305 days milk yield breeding value and standard error for individual animals were estimated by sum of multiplication of 305 days solutions of Legendre polynomials to random effect solutions of individual animals.

Best Linear Unbiased Prediction (BLUP) method (Mrode, 2014) [14]

Univariate model

Breeding value of each sire was obtained as BLUP solutions for the animal genetic component in the model. Three solutions corresponding to each order of Legendre polynomial was obtained from BLUP analysis and EBV for each DIM and 305 days was calculated as below:

Each animal has an order of polynomials for animal and p effects regression coefficients as solutions for animal and permanent environmental effects. These are not useful for ranking animals and need to be converted to breeding values for any particular day of interest. Usually, in dairy cattle, values are calculated for 305 days' yield.

The estimated breeding value from days 5 to 309 for animal k (EBV_{k305}) is calculated as:

$$EBV_{(k305)} = t\hat{u}_k; \text{ with } t \text{ containing elements } t_j = \sum_{i=5}^m \sum_{j=0}^{nr} \phi_{ij}$$

Where,

t = a row vector of order of polynomials for animal and p_e effects with the j^{th} elements equal to the sum of the j^{th} orthogonal polynomial from days 5 to 309

$\hat{u}_k$ = vector for the regression coefficient of animal k

Reliability of EBV

$$\text{Reliability} = 1 - \text{PEV}/G$$

Where,

G = variance component of sire

Predicted Error Variance (PEV) = square of standard error

Here, standard error obtained by the sum of multiplication of n^{th} order of Legendre polynomials to n number of breeding value solutions.

Comparison of TDMY and TDECM for Sire Evaluation

Sires were evaluated for test day milk yield (TDMY) and test day energy corrected milk (TDECM) and thereafter ranked as per their genetic merit. The comparison of TDMY and TDECM for sire evaluation was judged by using the following criteria:

Rank correlation

The Spearman's correlation was used to judge the effectiveness between breeding values of sires derived by TDMY and ECMY models. The rank correlation estimated as per Steel and Torrie (1960) [15]:

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

Where

r_s = rank correlation coefficient

n = number of sires under evaluation

d_i = difference of rank between paired items under two models

The significance of rank correlation was tested by t-test as given below and it was compared with t-table value with $(n-2)$ degree of freedom:

$$t = r_s \sqrt{\frac{n-2}{1-r_s^2}}$$

Where,

n = number of animals

Results and Discussion

The minimum, maximum, average values of EBV and the number of sires above and below the average of breeding value for 305D MY and 305D ECMY of Mehsana buffalo bulls predicted through univariate BLUP are presented in Table 2. The average EBV for 305D MY was found higher compare to transformed traits for milk energy correction. But, the estimates of maximum EBV for 305D ECMY found slightly higher than 305D MY except for 305D 6% FCMY and highest breeding value (437.09 kg) found for the sire of 305D ECMY1. Similar to present study, Prajapati *et al.* (2018) [16] reported maximum, minimum and average EBV (Kcal) for fat based energy corrected milk were 1472.75, 978.94 and 1185.70 respectively for Mehsana buffalo. Earlier, Sathwara *et al.* (2019) [17] reported higher maximum, minimum and average EBV (kg) for first lactation fat yield were 135.71, 176.22 and 104.85 using univariate BLUP-AM for Mehsana buffalo. Upadhyay (2016) reported maximum, minimum and average EBV (kg) for first lactation 305D MY for Murrah buffaloes were 2077.76, 1622.65 and 1874.67 using BLUP-AM which found higher EBV as compared to Mehsana buffaloes.

The number of sires with positive and negative estimated breeding values (EBVs) for all sires ($n = 118$) as well as sires with 60% and above for reliability for 305D MY and 305D ECMY are presented in Table 3. The higher number of sires belonged to 305D MY as compared to 305D ECMY so it is suggestive of selection performed only based on milk yield may lead to overall decrease in the efficiency of sires. The number of sires with different classes of reliability percent (R%) are shown in Table 4. The highest number of sires found within 70-80% class of reliability followed by 60-70% class of reliability for all traits.

Rank correlation of sires' estimated breeding values for different traits

Rank correlation coefficients of 305D MY and 305D ECMY for all the sires (118 sires of daughters whose records were used for analysis) as well as for top and bottom 75%, top and bottom 50%, top and bottom 25% and top and bottom 10% sires based on their breeding values irrespective to reliabilities and greater than or equal to 60% reliability of EBVs estimated and are presented in Table 5 and 6 respectively. The rank correlation of sires EBVs between 305D MY and 305D ECMY for all sires, top 75%, top 50%, top 25%, top 10%, bottom 75%, bottom 50%, bottom 25% and top 10% were found highly significant for all traits while it was significant for top 10% bulls. The rank correlations of sire EBVs between 305D MY and 305D ECMY with greater than or equal to 60% reliability, were found highly significant for all sires, top 75%, top 50%, bottom 75%, bottom 50% and bottom 25% whereas correlation was significant for top 25% and bottom 10% except for 305D 4% FCMY and 305D 6% FCMY while non-significant for top 10% for all traits and bottom 10% for 305D 4% FCMY and 305D 6% FCMY. The above results indicated the huge changes in ranking of sires if selected based on 305D ECMY as compared to selected based on 305D MY in Mehsana buffalo.

Table 1: Energy correction formulas used in the present study

No.	Energy correction traits	Formula (From solids expressed as %)	References
1.	4% FCM (kg)	$0.4 * \text{Milk(kg)} + 15 * \text{Fat \% (kg)}$	Gaines, 1928 ^[7]
2.	6% FCM (kg)	$0.4 * \text{Milk(kg)} + 15 * \text{Fat \% (kg)/1.3}$	Rice, 1970 ^[8]
3.	ECM1 (lb)	$0.327 * \text{Milk yield (lb)} + 12.95 * \text{Fat (lb)} + 7.65 * \text{Protein (lb)}$	Tyrrell and Reid, 1965 ^[9]
4.	ECM2 (kg)	$\{\text{Fat yield (kg)} * 38.3 + \text{Protein yield (kg)} * 24.2 + \text{Milk yield (kg)} * 783.2\}/3.14$	Sjaunja <i>et al.</i> , 1990 ^[10]
5.	FPCM (kg)	$\text{TDMY (kg)} * [0.337 + \{0.116 * \text{Fat \% (kg)}\} + \{0.06 * \text{Protein \% (kg)}\}]$	CVB feed, 2016 ^[11]
6.	SCM (lb)	$12.3 * \text{Fat (lb)} + 6.56 * \text{SNF (lb)} 0.0752 * \text{Milk yield (lb)}$	Tyrrell and Reid, 1965 ^[9]

Table 2: Estimated breeding values (EBVs) of sire for 305D MY and 305D ECMY

Category	EBVs (kg)						
	305D MY	305D 4% FCMY	305D 6% FCMY	305D ECMY1	305D ECMY2	305D SCMY	305D FPCM
Maximum	356.70	400.86	308.43	437.09	397.59	404.21	396.04
Minimum	-275.06	-447.07	-344.01	-475.70	-437.71	-432.12	-427.88
Average	1.45	-2.13	-1.64	-1.80	-1.74	-2.26	-0.51
No. of sires above avg. BV	64 (54.24%)	63 (53.39%)	63 (53.39%)	62 (52.54%)	62 (52.54%)	62 (52.54%)	62 (52.54%)
No. of sires below avg. BV	54 (45.76%)	55 (46.61%)	55 (46.61%)	56 (47.46%)	56 (47.46%)	56 (47.46%)	56 (47.46%)

Table 3: Number of sire with positive (+ve) and negative (-ve) estimated breeding values (EBVs) for all sires and sires with equal to or greater than 60% reliability for 305D MY and 305D ECMY

Category	All sires included (n = 118)							Sires with greater than 60% reliability						
	305D MY	305D 4% FCMY	305D 6% FCMY	305D ECMY1	305D ECMY2	305D SCMY	305D FPCM	305D MY	305D 4% FCMY	305D 6% FCMY	305D ECMY1	305D ECMY2	305D SCMY	305D FPCM
								n = 60	n = 51	n = 51	n = 53	n = 53	n = 52	n = 53
+ve EBVs	64 (54.24)	61 (51.69)	61 (51.69)	60 (50.85)	60 (50.85)	60 (50.85)	60 (50.85)	33 (55.00)	24 (47.06)	24 (47.06)	26 (49.06)	26 (49.06)	25 (48.08)	26 (49.06)
-ve EBVs	54 (45.76)	57 (48.31)	57 (48.31)	58 (49.15)	58 (49.15)	58 (49.15)	58 (49.15)	27 (45.00)	27 (52.94)	27 (52.94)	27 (50.94)	27 (50.94)	27 (51.92)	27 (50.94)

(NB: Figures in parentheses shows the % sires)

Table 4: Number of sires with different classes of reliability percent (R%) for 305 DMY and 305 DECMY

Classes of reliability %	305D MY	305D 4% FCMY	305D 6% FCMY	305D ECMY1	305D ECMY2	305D SCMY	305D FPCM
Below 50	46 (38.98)	54 (45.77)	54 (45.77)	53 (44.92)	53 (44.92)	53 (44.92)	53 (44.92)
50-60	13 (11.01)	14 (11.86)	14 (11.86)	13 (11.01)	14 (11.86)	14 (11.86)	13 (11.01)
60-70	13 (11.01)	22 (18.64)	22 (18.64)	19 (16.10)	19 (16.10)	19 (16.10)	19 (16.10)
70-80	28 (23.73)	27 (22.88)	27 (22.88)	29 (24.58)	28 (23.73)	28 (23.73)	29 (24.58)
80-90	18 (15.27)	1 (0.85)	1 (0.85)	4 (3.39)	4 (3.39)	4 (3.39)	4 (3.39)

(NB: Figures in parentheses shows the % of sires)

Table 5: Rank correlation between breeding values for the sires of 305D MY and 305D ECMY

Category	n	305D 4% FCMY	305D 6% FCMY	305D ECMY1	305D ECMY2	305D SCMY	305D FPCM
All sires	118	0.94**	0.94**	0.95**	0.95**	0.95**	0.96
Top 75%	86	0.89**	0.89**	0.91**	0.91**	0.90**	0.92
Top 50%	59	0.81**	0.81**	0.87**	0.86**	0.86**	0.87
Top 25%	30	0.60**	0.60**	0.72**	0.70**	0.73**	0.74
Top 10%	11	0.63*	0.63*	0.69*	0.66*	0.67*	0.69
Bottom 75%	86	0.88**	0.88**	0.91**	0.90**	0.91**	0.91
Bottom 50%	59	0.83**	0.83**	0.86**	0.86**	0.88**	0.87
Bottom 25%	30	0.61**	0.61**	0.72**	0.71**	0.71**	0.71
Bottom 10%	11	0.80**	0.80**	0.89**	0.89**	0.88**	0.89

Table 6: Rank correlation between breeding values for the sires of 305D MY and 305D ECMY at greater than or equal to 60% reliability for 305D MY

Category	305D 4% FCMY		305D 6% FCMY		305D ECMY1		305D ECMY2		305D SCMY		305D FPCM	
	n	P	n	P	n	P	n	P	n	P	n	P
All sires	51	0.94**	51	0.94**	53	0.95**	53	0.96**	52	0.96**	53	0.96**
Top 75%	38	0.90**	38	0.90**	40	0.93**	40	0.92**	39	0.93**	40	0.94**
Top 50%	26	0.78**	26	0.78**	27	0.86**	27	0.84**	26	0.84**	27	0.87**
Top 25%	13	0.56*	13	0.56*	13	0.79*	13	0.74*	13	0.79*	13	0.73*
Top 10%	5	0.3	5	0.3	5	0.1	5	0.1	5	0.1	5	0.1
Bottom 75%	38	0.93**	38	0.93**	40	0.95**	40	0.94**	39	0.94**	40	0.94**
Bottom 50%	26	0.84**	26	0.84**	27	0.84**	27	0.83**	26	0.85**	27	0.84**
Bottom 25%	13	0.79**	13	0.79**	13	0.84**	13	0.90**	13	0.86**	13	0.88**
Bottom 10%	5	0.7	5	0.7	5	0.9*	5	0.9*	5	0.9*	5	0.9*

Conclusion

High magnitude of change in ranking of sires if daughters selected based on ECMY as compared to MY may lead to change in the genetic gain under large-scale field-based animal breeding programmes. Thus, bulls selected for MY may produce less milk energy efficient daughters and it is required to select the bulls for 305D FPCMY for energy efficiency of milk yield. Hence, selection for energy corrected milk yield will require the use of different sires based on the ranking of sires for different traits. The selection based on TDMY is expected to result faster genetic gain in Mehsana buffalo. However, the selection of sire based on energy corrected milk is expected to the higher energy efficiency of milk and it may provide higher total revenues to farmers in context to fat or energy efficient milk.

References

1. FAO. World agriculture towards 2030/2050: the 2012 revision. Summary report. Rome: Food and Agriculture Organization of the United Nations; 2012 Jun.
2. FAO. Milk and dairy products in human nutrition. Rome: Food and Agriculture Organization of the United Nations; 2013.
3. FAOSTAT. FAO statistical database. Rome: Food and Agriculture Organization of the United Nations; 2012. Available from: <http://faostat.fao.org/>. Accessed 2012 Sep 21.
4. Perrin DR. The calorific value of milk of different species. *J Dairy Res.* 1958;25(2):215-220.
5. Hüttmann H, Stamer E, Junge W, Thaller G, Kalm E. Analysis of feed intake and energy balance of high-yielding first lactating Holstein cows with fixed and random regression models. *Animal.* 2009;3(2):181-188.
6. Ménard O, Ahmad S, Rousseau F, Briard-Bion V, Gaucheron F, Lopez C. Buffalo vs. cow milk fat globules: size distribution, zeta-potential, compositions in total fatty acids and in polar lipids from the milk fat globule membrane. *Food Chem.* 2010;120(2):544-551.
7. Gaines WL. The energy basis of measuring milk yield in dairy cows. *Bull Univ Illinois Agric Exp Stn.* 1928;308:1-80.
8. Rice VA. Breeding and improvement of farm animals. Bombay (India): McGraw Hill; 1970. p. 1-350.
9. Tyrrell HF, Reid JT. Prediction of the energy value of cow's milk. *J Dairy Sci.* 1965;48(9):1215-1223.
10. Sjaunja LO, Bævre L, Junkkarinen L, Pedersen J, Setälä J. Measurement of the total energy value of milk fat and milk protein. In: Proc 27th session of the International Committee for Breeding and Productivity of Milk Animals; 1990; Paris, France. p. 1-15.
11. CVB Feed. Chemical composition and nutritional values of feedstuffs. Wageningen (Netherlands): CVB Feed; 2016. p. 1-400.
12. Habib MA, Bhuiyan AFH, Amin MR, Khan MS. Comparison of different models for estimation of standardized 300-day milk yield from 15-day test interval records of Red Chittagong cattle in Bangladesh. *Asian-Australas J Biosci Biotechnol.* 2019;4(1):67-73.
13. Abramowitz M, Stegun IA. Handbook of mathematical functions. New York: Dover Publications; 1965. p. 1-1046.
14. Mrode RA. Linear models for the prediction of animal breeding values. 2nd ed. Cambridge (UK): CABI; 2014. p. 1-360.
15. Steel RGD, Torrie JH. Principles and procedures of statistics with special reference to the biological sciences. New York: McGraw-Hill; 1960. p. 1-550.
16. Prajapati BM, Gupta JP, Chaudhari JD, Parmar GA, Panchasara HH, Chauhan HD, Prajapati MN. First lactation production performance of Mehsana buffaloes under field progeny testing programme in semi-arid region of Gujarat. *Indian J Dairy Sci.* 2018;71(4):404-408.
17. Sathwara RN, Gupta JP, Chaudhari JD, Prajapati BM, Srivastava AK, Chauhan HD, Patel PA. Sire evaluation models for estimating breeding values of Mehsana buffaloes. *Indian J Anim Sci.* 2019;89(4):448-452.
18. Upadhyay A. Genetic evaluation of Murrah and Karan Fries bulls for energy corrected milk yield and fertility [doctoral thesis]. Karnal (India): ICAR-National Dairy Research Institute; 2016. p. 1-180.