



Covariance component and genetic parameter estimate of production and fertility traits in Holstein Friesian cross cattle using repeatability animal model

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ABSTRACT

The aim of present study was to estimate expected breeding value (EBV) using repeatability animal model and studying the efficiency of bivariate repeatability model over univariate repeatability model, on the basis of performance records pertaining to fertility and production traits in Holstein Friesian crossbred cattle. Lactation records (5,878) on 1,988 crossbred cows sired by 186 bulls, spread over a period of 34 years (1978 – 2012) were analysed in the study. Estimates of covariance components and genetic parameters for fertility and production traits were obtained using restricted maximum likelihood (REML) approach using average information (AI) algorithm. Estimates of heritability obtained by AIREML were significantly lower in fertility traits in comparison to the production traits. Repeatability model helped in the partitioning of additive, permanent environment and residual variances and thus the upwardly bias due to permanent environment in estimation of additive variance was prevented. The genetic parameter estimates of bivariate repeatability animal model were superior in comparison to the estimates of univariate model. The genetic correlation estimates indicated unfavourable association between fertility and production traits. The bivariate repeatability model had greater potential in identification of sires with higher genetic merit for fertility and production traits.

Key words: Bivariate, Fertility, Holstein Friesian cross, Repeatability model

In India, contribution of dairy cattle to total milk production is about 43.38% of the milk production, out of which crossbred cattle contribute around 51.28% (FAOSTAT 2014). As per 18th Indian livestock census, cattle population in India increased by about 7.5% and population of exotic and crossbred cattle increased by 35%. The total share of crossbreds in the cattle population showed an increase of 16.6%. Moreover, higher productive and reproductive efficiency of crossbred cattle in comparison to indigenous cattle, make them more profitable. Over the years various strains of crossbred cattle have been developed in country, as a result of different crossbreeding projects that were undertaken in different institute herds to increase the productivity of indigenous breeds of dairy cattle.

Most of the research on the estimation of genetic parameters of production and fertility traits, in Indian

crossbred cattle, was done mainly by analysis of variance and on the basis of first lactation records. The analysis of variance (ANOVA) used for the estimation of covariance components is more applicable under controlled breeding experiments (Meyer 1989, Lee and Werf 2006). The conventional methods of sire evaluation such as the simple regressed least squares and contemporary comparison method are done on the basis of single records obtained for the economic traits and do not consider the performance of the animal in succeeding lactations (Van Vleck and Gregory 1992, Bernabucci *et al.* 2014). Selection of crossbred cattle has so far been focused on the production performances only. A multitude of studies in dairy cattle have suggested that selection for higher milk yield alone is associated with an unfavourable correlated response in female fertility (Jorjani 2006 and Hammound *et al.* 2010). Therefore, it is imperative to overcome the deterioration in reproductive traits. More emphasis should be given for incorporating fertility traits in selection strategy of crossbred cattle.

The present study focuses comparative efficiency of bivariate over univariate repeatability models in estimation of expected breeding values (EBVs) in Holstein Friesian crossbred cattle. Estimation of variance components was done by restricted maximum likelihood (REML) approach using average information (AI) algorithm.

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MATERIALS AND METHODS

Data structure: Data available for analysis were collected from Holstein Friesian crossbred cattle herd, maintained at National Dairy Research Institute (NDRI), Karnal, situated in the Trans-gangetic plain, in the eastern zone of Haryana. The data comprised 5,878 lactation records on 1,988 Karan Fries cows sired by 186 bulls, spread over a period of 34 years from 1978 to 2012.

Data classification: Considering the cumulative effect of changing management practices and environment on the performance of the dairy cow, the data were classified into 6 periods of calving, each comprising a span of 5 years. Calvings were distributed in all the 4 seasons of a year. Lactation records were also classified based on parity order and 5 groups were formed namely first, second, third, fourth and fifth parity. The fifth parity actually comprised records on fifth and above parities. For genetic analysis only the records pertaining to the interbred population of Karan Fries cattle were considered.

Traits studied: Six production and fertility traits were considered for analysis, viz. days open (DO), calving interval (CI), calving to first service (CFS), lactation length (LL), 305 day milk yield (305MY), total milk yield (TMY). Repeated records of these traits were obtained for analysis.

Statistical methods: Data were first analyzed by least squares model using SAS 9.3 software package (2011), to identify significant ($P < 0.05$) nongenetic factors to be included in the repeatability model. Covariance components were estimated by restricted maximum likelihood (REML) method using average information (AI) algorithm of WOMBAT (Meyer 2007). These estimates were fitted into univariate and bivariate repeatability model (taking into account effect of permanent environment on the production and fertility traits). The following repeatability model was used for uni and bivariate analysis,

$$y = Xb + Za + Wpe + e$$

where, y , observation vector of records; X , incidence matrix for fixed effects; Z , incidence matrix for random effect; W , incidence matrix relating records to permanent environmental effects; a , vector of random effect; b , vector for fixed effects; pe , vector of permanent environmental effects; e , vector of random residual effects. Permanent environmental effects and residual effects were assumed to be normally independently distributed with means zero and variance σ_c^2 and σ_e^2 , respectively. Repeatability estimates were obtained from the univariate repeatability analysis. The phenotypic and genetic correlation estimates were obtained using bivariate repeatability model. Analysis by bivariate repeatability model was done by considering fertility with production as a secondary trait.

RESULTS AND DISCUSSION

The coefficient of variation (CV) was higher for fertility traits in comparison to production traits. The results of least squares analysis revealed significant effect of season and period of calving, parity and genetic group on almost all traits considered for present study (Table 1).

Estimates of variance components: The estimates of genetic parameters by univariate and bivariate analysis for the fertility and production traits are detailed in Tables 2, 3 and 4. The estimates of repeatability (r) of CFS, DO and CI were higher in comparison to heritability (h^2) estimates for CFS and CI, respectively. The heritability (h^2) for CFS was similar to ratio of permanent environmental variance (c^2) estimate (0.06). Permanent environmental variance of DO and CI were higher than h^2 estimates. High estimates of residual variance (σ_e^2) indicated the effect of management and environment on these traits. The repeatability estimates were low for all the fertility traits. The estimates of σ_a^2 and h^2 by bivariate model, with 305MY as the secondary trait,

Table 1. Data structure and least squares means and effect of different factors affecting production and reproduction traits in Karan Fries cattle

	CFS (days)	DO (days)	CI (days)	LL (days)	305MY (kg)	TMY (kg)
LSM	78.21 $\pm$ 1.59	115.46 $\pm$ 2.14	403.91 $\pm$ 2.54	326.57 $\pm$ 2.60	3634.78 $\pm$ 30.91	3976.77 $\pm$ 41.03
SD	31.17	58.00	72.10	86.28	1033.44	1353.24
CV%	40.86	50.63	17.83	26.95	30.75	37.11

Table 2. Estimates of variance components of production and fertility traits using univariate repeatability model in Karan Fries cattle

Estimates ^a	CFS	DO	CI	LL	305MY	TMY
σ_a^2	52.04	33.30	140.12	275.35	133545.00	200705.00
σ_c^2	55.82	265.10	242.18	385.79	148411.00	273904.00
σ_e^2	796.10	2943.99	4492.29	5766.54	651896.00	1144550.00
$h^2 \pm SE$	0.06 $\pm$ 0.04	0.00 ^c	0.03 $\pm$ 0.02	0.04 $\pm$ 0.02	0.14 ^b	0.12 ^b
$c^2 \pm SE$	0.06 $\pm$ 0.04	0.08 $\pm$ 0.03	0.05 $\pm$ 0.03	0.06 $\pm$ 0.02	0.16 ^b	0.17 ^b
r	0.12	0.08	0.08	0.10	0.30	0.29

^aestimates of variance components σ_a^2 , σ_c^2 and σ_e^2 ; $h^2 = \sigma_a^2 / \sigma_p^2$, $c^2 = \sigma_c^2 / \sigma_p^2$ and $r(\text{Repeatability}) = (\sigma_a^2 + \sigma_c^2) / (\sigma_a^2 + \sigma_c^2 + \sigma_e^2)$.
^bindicate failure in approximation of standard error (SE). ^cestimate is below 0.01.

Table 3. Estimates of variance components of fertility and production traits using bivariate repeatability model in Karan Fries cattle

Estimates ^a	CFS	DO	CI	LL	305MY ^e	305MY ^f	305MY ^g	305MY ^h
σ_a^2	59.98	33.31	170.40	345.57	136768.00	136967.00	140358.00	143062.00
σ_c^2	49.74	265.10	248.93	496.13	146252.00	148750.00	147144.00	176300.00
σ_e^2	795.62	2943.99	4469.54	5617.90	651796.00	650450.00	650023.00	638036.00
$h^2 \pm SE$	0.07 $\pm$ 0.04	0.01 $\pm$ 0.02	0.04 $\pm$ 0.02	0.05 $\pm$ 0.02	0.15 ^b	0.15 ^b	0.15 ^b	0.15 ^b
$c^2 \pm SE$	0.06 $\pm$ 0.04	0.08 $\pm$ 0.03	0.05 $\pm$ 0.03	0.08 $\pm$ 0.02	0.16 ^b	0.16 ^b	0.16 ^b	0.18 ^b
r	0.12	0.10	0.09	0.13	0.30	0.31	0.31	0.33

^aestimates of variance components σ_a^2 , σ_c^2 and σ_e^2 ; $h^2 = \sigma_a^2/\sigma_p^2$ and $c^2 = \sigma_c^2/\sigma_p^2$ and $r(\text{Repeatability}) = (\sigma_a^2 + \sigma_c^2)/(\sigma_a^2 + \sigma_c^2 + \sigma_e^2)$; ^bindicate failure in approximation of standard error (SE); ^cestimates of 305MY from bivariate model with CFS; ^festimates of 305MY from bivariate model with DO and ^gestimates of 305MY from bivariate model with CI; ^hestimates of 305MY from bivariate model with LL.

Table 4. Estimates of variance components of fertility and production traits using bivariate repeatability model in Karan Fries cattle

Estimates ^a	CFS	DO	CI	LL	TMY ^e	TMY ^f	TMY ^g	TMY ^h
σ_a^2	60.97	70.23	240.42	459.33	202687.00	204216.00	217438.00	226854.00
σ_c^2	49.49	267.09	262.98	625.72	274047.00	284250.00	278983.00	377688.00
σ_e^2	795.69	2921.67	4419.27	5389.99	1143820.00	1137910.00	1135840.00	1088420.00
$h^2 \pm SE$	0.07 $\pm$ 0.04	0.02 $\pm$ 0.02	0.05 $\pm$ 0.03	0.07 $\pm$ 0.02	0.13 ^b	0.13 ^b	0.13 ^b	0.13 ^b
$c^2 \pm SE$	0.06 $\pm$ 0.04	0.08 $\pm$ 0.03	0.05 $\pm$ 0.03	0.09 $\pm$ 0.02	0.17 ^b	0.18 ^b	0.17 ^b	0.22 ^b
r	0.12	0.10	0.10	0.17	0.29	0.30	0.30	0.36

^aestimates of variance components σ_a^2 , σ_c^2 and σ_e^2 ; $h^2 = \sigma_a^2/\sigma_p^2$ and $c^2 = \sigma_c^2/\sigma_p^2$ and $r(\text{Repeatability}) = (\sigma_a^2 + \sigma_c^2)/(\sigma_a^2 + \sigma_c^2 + \sigma_e^2)$; ^bindicate failure in approximation of standard error (SE); ^cestimates of TMY from bivariate model with CFS; ^festimates of TMY from bivariate model with DO and ^gestimates of TMY from bivariate model with CI; ^hestimates of TMY from bivariate model with LL.

Table 5. Estimates of phenotypic and genetic correlation between the production and fertility traits in Karan Fries cattle

Estimates ^d	305MY				TMY			
	r_p	r_g	r_c	r_e	r_p	r_g	r_c	r_e
CFS	0.05 $\pm$ 0.02	0.09 $\pm$ 0.27	0.07 $\pm$ 0.28	0.04 $\pm$ 0.00 ^c	0.08 $\pm$ 0.02	0.26 $\pm$ 0.27	0.08 $\pm$ 0.27	0.055 $\pm$ 0.001
DO	0.10 $\pm$ 0.02	1.00 ^d	0.07 $\pm$ 0.18	0.063 $\pm$ 0.00 ^c	0.15 $\pm$ 0.01	1.00 ^d	0.12 $\pm$ 0.16	0.101 $\pm$ 0.002
CI	0.10 $\pm$ 0.01	0.51 $\pm$ 0.27	0.09 $\pm$ 0.03	0.07 $\pm$ 0.03	0.16 $\pm$ 0.02	0.72 $\pm$ 0.19	0.14 $\pm$ 0.04	0.11 $\pm$ 0.03

Estimates of phenotypic (r_p), genetic (r_g), common environmental (r_c) and residual correlation (r_e); ^cestimate is below 0.01; ^d r_g estimate is unrealistic.

were higher than the univariate model for all fertility traits; whereas the estimates of σ_c^2 and c^2 were similar to those of univariate model.

Production traits: The production traits considered for analysis indicated greater direct additive and permanent environmental variance in comparison to fertility traits. Estimates of c^2 were higher than h^2 as in fertility traits. The heritability estimates of production traits were sizable and repeatability estimates indicated that these traits were moderately repeatable. Similar to the fertility traits the estimates of σ_a^2 and h^2 by bivariate model for 305MY were higher than the univariate model estimates, whereas the σ_c^2 and c^2 estimates were similar to those of univariate model.

Phenotypic and genetic correlation estimates

Phenotypic, genetic, permanent environmental and residual correlation estimates are detailed in the Table 5.

CFS with production traits: Very low estimates of r_p , r_g , r_c and r_e were obtained for CFS with 305MY. The r_p , r_g , r_c

and r_e estimates of CFS with TMY were 0.08, 0.26, 0.08 and 0.06.

DO with production traits: Days open (DO) was viewed as the upper limit of CFS and the r_p , r_c and r_e with 305MY and TMY were 0.10, 0.07, 0.063 and 0.15, 0.12, 0.10, respectively.

CI with production traits: Calving interval indicated the overall performance related to cyclicity, conception as well as normal gestation of crossbred cows. The r_p , r_g , r_c and r_e estimates of calving interval with 305MY and TMY were 0.10, 0.51, 0.09, 0.07 and 0.16, 0.72, 0.14, 0.11 respectively. Genetic correlation was very high and all correlation estimates were positive.

Univariate and bivariate repeatability model analysis: Bivariate analysis was carried out by considering a fertility trait (DO or CI) with a production trait (305MY or TMY); the efficacy of bivariate model over univariate model was compared on the basis of error variance and standard deviation of expected breeding values (EBVs). The error

variance of bivariate model was lesser in comparison to univariate repeatability model. Moreover, all bivariate models attempted under the current study had greater standard deviation of predicted breeding values, indicating greater potential of this model in indentifying sires with higher genetic merit. The error variance estimates of (σ_e^2) of univariate models for CFS and CI were lower than in bivariate model estimates 795.62 days² (CFS) and 4469.54 days² (CI). The σ_e^2 estimate was similar for DO in both uni and bivariate repeatability models. The standard deviation of breeding values of fertility traits CFS (2.86 days) and CI (5.52 days) estimated by bivariate repeatability model was higher than univariate repeatability model.

The estimates of error variance (σ_e^2) of univariate model for 305MY was higher than the error variance of all bivariate models attempted. Further, the range of standard deviation (SD) of breeding values estimated for 305MY by bivariate repeatability model was 220.78 to 251.85 kg. Similarly, the range of SD for breeding values in TMY, estimated by similar model, was 254.89 to 294.35 kg (Tables 6, 7).

Genetic evaluation of production along with fertility traits can make a difference to dairy producers by improving economic efficiency of dairy farming. The focus of the present study was to estimate genetic parameters and

breeding values using advanced animal repeatability model; as well as studying the efficiency of bivariate repeatability model over univariate repeatability model, on the basis of repeated records pertaining to fertility and production traits in Holstein Friesian crossbred cattle. Repeatability model helped in the partitioning of additive, permanent environment and residual variances and thus the upwardly bias due to permanent environment in estimation of σ_a^2 was prevented.

Weigel and Rekaya (2000) reported h^2 estimate to be 0.06 for fertility trait CFS in Holstein cattle. Kadarmideen *et al.* (2003) obtained h^2 estimate of CFS as 0.03, which was lower than that estimated under present study. Ghaisi *et al.* (2011) reported the heritability estimate to be 0.06 in Iranian Holsteins. Divya (2012) reported an estimate of 0.02 for CFS using univariate animal model on first lactation record in Karan Fries cattle. Days open (DO) is a function of CFS and the number of missed cycles between first service and successful service. The h^2 of DO in the present study was lower than the estimates of 0.02 and 0.07 by Kadarmideen *et al.* (2003) and Sun *et al.* (2010) respectively. The current estimate lied in the range of 0.15 to 0.10 (Lazarevic and Miscevic 2005, Petrovic *et al.* 2007). Calving interval (CI) indicated the overall fertility performance between 2 successive calvings; the heritability estimate for the trait was lower than reported by Mariam *et al.*, (2003) and Ojango *et al.* (2005) 0.09 and 0.05, respectively. Divya (2012) and Sun *et al.* (2010) reported a higher estimate of 0.05 and 0.07 of calving interval based on first lactation records in Karan Fries and Danish Holsteins respectively.

The heritability estimate of production trait 305MY (0.14) obtained under current study was lower than 0.28 and 0.29 reported by Kadarmideen *et al.*, (2003) and Kadarmideen (2004), respectively. Heritability estimates of 305MY based on first lactation records were 0.23 and 0.39 by Divya (2012) and Sun *et al.*, (2010) respectively. Nehara *et al.* (2013) estimated higher heritability for 305MY (0.48) using first lactation records of Karan Fries cattle. Estimated heritability (0.27) for TMY (Tekerli and Kocak, 2009) on the basis of first lactation records was higher than the estimate (0.12) in the present study. Similar heritability estimates of 0.61 were obtained for both MY/LL and MY/CI, on the basis of first lactation records using analysis of variance method in Karan Fries cattle (Nehara *et al.* 2013), the estimates were higher than that obtained in the current analysis.

The repeatability estimates obtained for CI, TMY, MY/LL, MY/CI were lower than the estimates of repeatabilities for CI (0.10), TMY (0.43), MY/LL (0.51) and MY/CI (0.41) reported by Tekerli and Kocak (2009) who estimated the variance components by univariate analysis of variance. The repeatability estimates for the current study were made on the assumption of $r_g = 1$ between repeated records i.e. the same trait expressed across different lactations. The c^2 estimates reported by Kadarmideen *et al.* (2003) for CFS (0.02), DO (0.02), CI (0.02) and 305MY (0.12) were lower

Table 6. Standard deviation (S.D.) of bivariate model considering production with fertility traits

Bivariate model	Trait	SD
CFS & 305MY	CFS	2.86
	305MY	220.78
DO & 305MY	DO	3.47
	305MY	251.85
LL & 305MY	LL	9.42
	305MY	225.46
CI & 305MY	CI	5.52
	305MY	254.92
CFS & TMY	CFS	3.01
	TMY	254.89
DO & TMY	DO	4.79
	TMY	284.99
LL & TMY	LL	11.47
	TMY	271.25
CI & TMY	CI	7.52
	TMY	294.35

Table 7. Standard deviation (S.D.) of univariate repeatability model

Trait	SD
CFS	2.83
DO	NE ^d
CI	4.20
LL	7.34
305MY	247.02
TMY	279.25

^dNE standard deviation not estimated as the constants estimated were very low and unrealistic.

than the estimates obtained in the present study. The c^2 estimates obtained in the present study indicated higher effect of permanent environment in comparison to additive gene action, on the performance with respect to fertility and production traits.

The phenotypic and genetic correlation estimates of fertility with production traits were positive and unfavourable. The genetic correlation estimates indicated that improvement in production traits would bring about unfavourable response or decline in performance with respect to fertility traits. Sun *et al.* (2010) reported the genetic correlation between CFS, DO and CI with 305MY to be in the range of 0.43 to 0.50. Makgahlela *et al.* (2007) reported an unfavourable estimate of genetic correlation (0.69) between CI and TMY on the basis of first lactation records. Kadarmideen *et al.* (2003) reported the genetic correlation between CI and DFS with 305MY to be 0.54 and 0.36 respectively. Similarly the estimates of residual environment (r_e) and permanent environmental correlation (r_{pe}) were 0.16, 0.13 and 0.82, 0.34, respectively. Unfavourable positive phenotypic correlation (r_p) estimates between fertility and production traits were obtained by Kadarmideen *et al.* (2003), Makgahlela *et al.* (2007) and Sun *et al.* (2010). The unfavourable correlation between the production and fertility traits indicated that with increased productivity of the dairy cattle the fertility would decline thus producing an unfavorable correlated response in the fertility traits.

Bivariate analysis was done by including a production trait (305MY or TMY) with a fertility trait (CFS or DO or CI). The production trait was included in the model as the selection criteria (secondary trait) and fertility trait was the selection objective (primary trait). Records on most of the fertility traits such as CFS, DO and CI are less available as culling of the cows is mostly done, keeping in view the production performance without taking into account the fertility performance. This introduces a selection bias in analysis of fertility traits as the cow's true fertility potential is not truly assessed. Therefore, including the production performance as a correlated trait in bivariate model accounted for this culling or selection bias (Kadarmideen *et al.* 2003, Sun *et al.* 2010). The results of the 2 trait analysis indicated that the bivariate repeatability models with production as the secondary trait had greater standard deviation and lower error or residual variance in comparison to univariate model which indicated their superiority in identifying sires with greater genetic merit for fertility trait. The estimates of error variance and standard deviation of bivariate repeatability model were superior for both production and fertility traits. Results comply with the findings of Jilek *et al.* (2008), Zink *et al.* (2012) and Pritchard *et al.* (2013).

The results indicated that fertility traits were lowly heritable and repeatable, in comparison to production traits and their genetic improvement was affected due to unfavourable correlation with production traits. Further, the bivariate model was more efficient than the univariate

repeatability model with lesser residual variance and greater differentiation potential for both fertility and production traits. Therefore, when multiple lactation records are available, sire evaluation in Karan Fries cattle should be done by multi-trait repeatability animal model giving emphasis to fertility performance along with production potential of the dairy cattle.

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