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Full Length Research Paper

Genetic evaluation of Ethiopian Boran cattle and their crosses with Holstein Friesian for milk constituent traits in central Ethiopia

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Breed additive and non-additive effects, and genetic parameters of milk fat, protein, solids not fat (SNF) and total solids (TS) percents, were estimated in Ethiopian Boran cattle and their crosses with Friesian in central Ethiopia. Ethiopian Boran cattle were consistently superior (*P*<0.01) to the Ethiopian Boran-Holstein Friesian crosses for the milk composition traits studied. When the crosses were compared, the fat, protein, SNF and TS percents of 50 and 62.5% Holstein Friesian crosses were higher (P<0.01) than those of 75 and 87.5% genetic groups. The 50 and 62.5% genetic groups did not differ (P>0.05) in milk constituents. It was apparent, therefore, that as the exotic gene level increased the percentages of the milk constituents declined significantly. The individual additive genetic breed difference for milk composition traits were all significant (*P*<0.01). The estimates were -1.45 for fat, -0.97 for protein, -1.13 for SNF and -2.47 for TS percents. Crossbreeding of the Holstein Friesian with the Ethiopian Boran resulted in desirable and significant (at least *P*<0.05) individual heretosis for all milk composition traits. The estimates were 0.54 ± 0.09, 0.25 ± 0.10, 0.33 ± 0.15 and 0.72 ± 0.18 for fat, protein, SNF and TS percents, respectively. The maternal heterotic effects were non-significant (*P*>0.05) for all traits except for fat percent. Heritabilities of fat, protein, SNF and TS percents for Ethiopian Boran were 0.49 ± 0.03, 0.26 ± 0.05, 0.46 ± 0.04 and 0.45 ± 0.04, respectively. The corresponding estimates for crosses were 0.32 ± 0.04, 0.49 ± 0.03, 0.39 ± 0.04 and 0.41 ± 0.04, respectively. Within Ethiopian Boran breed selection accompanied by crossing should enormously improve these traits in crossbreds under such production system.

Key words: Genetic evaluation, genetic parameter, Ethiopian Boran, Holstein Friesian.

INTRODUCTION

The livestock sector has a significant contribution to the national economy of Ethiopia. However, production per animal is extremely low. The average lactation milk production for the indigenous cows ranges from 494 - 850 kg under optimum management (EARO, 1999).

To meet the ever-increasing demand for milk and milk products in Ethiopia, genetic improvement of the indigenous cattle has been proposed as one of the options Ge-netic improvement of the indigenous cattle, basically focusing on crossbreeding, has been practiced for the last five decades but with little success. Understandably, milk yield has been the single most important trait of dairy improvement programs. However, several studies have shown that milk constituent percents decline with increased milk yield. Indeed, in most of tropical countries where milk is sold on the basis of volume than its constituents, the later would attract little focus from breeders perspective. Consequently, there have been relatively few studies from tropical and subtropical areas on milk constituents. In Ethiopia, there are essentially no studies

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Table 1. Number of records available

Trait	Herd		Genetic group				
	Debre Zeit	Holeta	E. Boran	50%	62.5%	75%	87.5%
Fat %	1545	3802	1555	2494	743	393	150
Protein %	1473	3949	1592	2579	737	376	126
SNF %	1422	3809	1555	2471	733	352	112
TS %	1411	4007	1619	2580	747	352	111

carried out to date. However, the future trend clearly indicates that milk constituent traits be considered in breed improvement programs. For these to be achieved factors affecting the constituent traits, genetic and crossbreeding parameter estimates should be made available. This paper reports on factors affecting the milk constituents, genetic parameters and crossbreeding parameters of milk constituents from original studies on Ethiopian Boran and their crosses with Holstein-Friesian in central Ethiopia.

MATERIALS AND METHODS

Source of data

Data for the study were collected from experimental dairy cattle herds of Ethiopian Boran and Ethiopian Boran-Holstein Friesian crossbred cattle maintained at the Debre Zeit Research Station of the International Livestock Research Institute (ILRI) and at the Holeta Agricultural Research Centre of the Ethiopian Institute of Agricultural Research (EIAR).

Description of the farms

The Debre Zeit Research Station of the International Livestock Research Institute (ILRI) is located on the outskirts of the town of Debre Zeit, about 50 km south-east of Addis Ababa, in the Ethiopian highlands (9º N and 39º E), at an altitude of about 1850 m above sea level. Average annual rainfall in the Debre Zeit area is about 866 mm. The annual average temperature is 18.7ºC and the average monthly relative humidity is 52.4%.

The Holeta Agricultural Research Centre is located 45 km west of Addis Ababa at 38.5ºE longitude and 9.8º N latitude, and elevation of 2400 m above sea level. It is situated in the central highlands of Ethiopia. The average annual rainfall is about 1200 mm and the average monthly relative humidity is 60.6%.

Animal management practices

The cattle in Debre Zeit farm were not grazed because of problem of tick infestation. Thus, they were all stall-fed. Clean water, hay and mineral lick were provided *ad libitum.* Additionally, animals had free access to teff (*Eragrostis tef*) straw. The animals were supplemented with concentrate mixture composed of wheat bran, noug seed cake (*Guizoita abysinica)*, and molasses, based on milk production, two times per day. All calves were weighed at birth and allowed to suckle their dams for the first 24 h in order to obtain colostrum, after which they were moved to individual calf pens for bucket feeding (3 liters milk per day) until weaning (57 days). Milking was done by hand twice a day (morning, 5:00 am and evening 5:00 pm). Culling was based on production (low producers), age (old age) and health problems. Disease control was practiced through combined health management practices that included vaccination for the major diseases (Black Quarter, Anthrax, Contagious Bovine Pleuro Pneumonia, Pasteurellosis and Foot-and-Mouth Disease), regular de-worming (every six months) and treatment as diseases occurred.

The herd at Holeta was grazed on natural pasture for about 8 h during daytime. At night all animals were housed and supplemented with natural pasture hay conserved from part of the grazing area. Except for the lactating cows, which were supplemented with approximately 3 – 4 kg of concentrate at each milking, no other animal received any regular concentrate supplement. Occasionally, during the long-dry period and based on the condition of the animals, dry and young stocks were supplemented with some (unspecified) amount of concentrate. All animals had free access to clean water. Cows and heifers were all reared in a similar environment with fairly constant management. All calves were weighed at birth and allowed to suckle their dams for the first 24 h in order to obtain colostrum, after which they were moved to individual calf pens for bucket feeding until weaning at 90 days of age. Each calf was fed a fixed total of 260 kg of whole milk during the pre-weaning period. Weaned calves were kept indoors until the age of 6 months, during which they were fed *ad lib* on natural pasture hay and supplemented with approximately 1 kg per day per animal of concentrate composed of 30% wheat bran, 32% wheat middling, 37% noug seedcake (*Guizoita abysinica*) and 1% salt. At 6 months of age, all animals were grazed in a group on natural pastures for about 8 h a day and supplemented with conserved natural pasture hay at night.

In both herds cows were bred using AI, and there were no heat induction and/or synchronization protocols.

Data analysis

The total number of records available for analysis is summarized in Table 1. Traits studied were fat, protein, solids-not-fat (SNF) and total solids (TS) percents. Least squares analysis was carried out to make genotype comparisons and study fixed effects (SAS, 2002). The fixed effects fitted were genotype (5 classes: Ethiopian Boran, 50, 62.5, 75 and 87.5% Holstein Friesian inheritance); cow parity (5 classes: 1, 2, 3, 4 and 5+); calving season, grouped into three classes, based on the pattern of annual rainfall distribution in the area as dry period (November - February), light rains (March – June) and main rainy season (July – October); and herd classes (Debre Zeit and Holeta). Two-way interactions of effects were also fitted in the models and retained in the final model when found significant (P<0.05) in preliminary analysis. Tukey-Kramer test was used to separate least squares means with more than two levels. The statistical model is described as follows:

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + H_l + eijklm$$

Where, Y_{ijklm} is the milk constituent traits; μ is the overall mean; G_i is the fixed effect of the i^{th} Genotype; P_j is the fixed effect of j^{th} cow

Table 2. Least squares means (± SE) for effects of genetic group, season, herd and parity on milk composition traits

Effect and level	Fat (%)	Protein (%)	SNF (%)	TS (%)
N	4036	4119	3943	4130
Overall	4.58±0.02	3.33±0.02	8.35±0.04	13.0±0.04
CV%	18.4	15.5	11.9	9.8
Genetic groups	**	*	**	**
50% HF	4.77±0.03[a]	3.40±0.02[a]	8.49±0.05[a]	13.19±0.05[a]
62.5% HF	4.85±0.04[a]	3.43±0.03[a]	8.43±0.05[a]	13.26±0.05[a]
75% HF	4.21±0.05[b]	3.07±0.03[b]	8.09±0.06[b]	12.44±0.08[b]
87.5% HF	4.04±0.08[c]	3.13±0.06[b]	8.06±0.11[b]	12.27±0.13[b]
Eth. Boran	5.01±0.03[d]	3.60±0.02[c]	8.66±0.05[c]	13.71±0.04[c]
Herd	**	**	NS	NS
Debre Zeit	4.72±0.03	3.22±0.04	8.35±0.07	13.00±0.05
Holeta	4.44±0.03	3.43±0.02	8.34±0.04	12.95±0.05
Season	NS	**	**	**
Light rain	4.56±0.03	3.31±0.03[a]	8.26±0.05[a]	12.80±0.05[a]
Main rain	4.59±0.03	3.43±0.02[b]	8.27±0.05[a]	12.94±0.05[b]
Dry season	4.59±0.03	3.24±0.02[c]	8.50±0.05[b]	13.18±0.05[c]
Parity	**	NS	**	**
1	4.67±0.03[a]	3.37±0.02	8.51±0.03[a]	13.23±0.04[a]
2	4.69±0.03[a]	3.34±0.02	8.39±0.04[b]	13.18±0.05[a]
3	4.57±0.04[b]	3.31±0.03	8.30±0.06[b]	12.94±0.06[b]
4	4.55±0.05[b]	3.38±0.04	8.33±0.08[b]	12.84±0.07[bc]
5+	4.41±0.05[c]	3.23±0.08	8.19±0.15[b]	12.68±0.08[c]

*, P<0.05; **, P<0.01; NS, Non significant.
Least squares means with same superscript in the same column indicate non. significance.

Parity; S_k is the fixed effect of k^{th} Season of calving; H_l is the fixed effect of l^{th} Herd; e*ijklm* is the random error.

The (co)variance components and the resulting genetic parameters (heritability, genetic correlations and repeatability) were estimated using the Derivative-Free Restricted Maximum Likelihood (DFREML) computer package of Meyer (1998). Two data sets (Ethiopian Boran and crosses) were used for this analysis. Univariate analysis is undertaken for each trait within each data set for estimation of heritability and repeatability, whereas genetic correlations were estimated using bivariate analysis. A repeatability animal model was fitted, where direct additive effects plus permanent environmental effect due to repeated records per cow were available as random effects. The fixed effects fitted in the least squares analysis were fitted.

Multiple regression analysis (SAS, 2002) was also used to estimate crossbreeding parameters. For the regression analysis, coefficients of expected breed content and heterozygosity in the cow were fitted as covariates to obtain estimates of the individual additive (g_iF), individual heterosis (h_iBF) and maternal heterosis (h_mBF) effects using similar procedures to those of Hirooka and Bhuttyan (1995) and Kahi et al. (1995). Expected heterozygosity with respect to the genes of two breeds was calculated as the expected proportion of genes from the sire and dam which differed with respect to the two breeds. For example, the expected heterozygosity with respect to genes of the Ethiopian Boran (B) and Holstein Friesian (F), h_iBF, was calculated as (g^sBxg^dF) + (g^sFxg^dB) where *g*B and *g*F indicate proportions of genes coming from Ethiopian Boran and Holstein Friesian where as the superscripts **s** and **d** denote that the genes come from the sire and dam, respectively. Similarly, expected heterozygosity with respect to two breeds, were calculated for the genotype of the dam of cow and was denoted as h_mBF. Breed additive effects of, for example, F were calculated using the following formula: h_iF= ½(g_sF + g_dF). The breed additive effects for Holstein Friesian were estimated as deviations from the Ethiopian Boran. Thus, the full model included effects of g_iF, h_iBF and h_mBF as well as fixed effects described in the least squares analysis except genetic group.

RESULTS AND DISCUSSION

Fixed effects and genotype comparisons

Results of the least squares analysis for milk composition traits are summarized in Table 2. Differences in milk composition among the genetic groups were substantial. As expected, Ethiopian Boran had higher (P<0.01) milk constituents than all the crosses. It is established that Zebu give milk with higher percent of milk constituents compared to the temperate breed (Yadav et al., 1989; Rege et al., 1994). In a study that involved crosses of Jersey with Ghana Shorthorn and Sokoto Gudali cattle in a tropical environment, Rege et al. (1994) found a significant butterfat percentage in the locals compared with the crosses. The fat, protein, SNF and TS percentages of 50 and 62.5% Holstein Friesian crosses were also higher (P<0.01) than those of 75% and 87.5% genetic groups. The 50% and 62.5% genetic groups did not differ (P>0.05) in milk constituents. It was apparent, therefore, that as the exotic gene level increased the percentages of the milk constituents declined significantly. Yadav et al. (1989) and Yadav et al. (1989) compared Hariana halfbreds with Jersey, Brown Swiss and Holstein Friesian for fat and SNF percentages and found out that the groups significantly differed. Hariana-Jersey crosses had 0.59% and 0.79% more fat than Hariana-Brown Swiss and Hariana-Friesian crosses, respectively. In their studies, the same trend was observed for the SNF.

Season of calving did not have a significant effect (P>0.05) on fat percent. However, the protein, SNF and TS percents were affected (P<0.01) by season of calving. Cows which calved during the dry period had higher SNF and TS percentages compared to those which calved in both short and heavy rainy seasons. The protein percent, however, took the reverse trend. That is, cows which calved during the heavy rainy season had higher protein percent followed by those which calved during the short rainy season; those that calved during the dry season had the least protein percent. Some workers (Singh et al., 1979; Yadav et al., 1989; Yadav et al., 1989) have noted seasonal variation in milk composition traits. However, consistent with the present study, they didn't find clear–cut differences.

The SNF and TS percents of the two farms did not differ significantly (P>0.05). The fat and protein percents, however, differed (P<0.01) between the two herds. Indeed, fat percent was higher for Debre Zeit herd compared to Holeta herd. However, the protein percent was higher for Holeta herd. This inconsistent difference between the two herds might point to the lack of real difference between the two herds in milk constitute traits.

The trend for percents of milk constituents associated with parity followed a well established pattern except for protein percentage. Fat percentage peaked numerically at second parity. However, SNF and TS percentages were highest at first parity, and declined significantly (P<0.01) to the 5th parity. Protein percentage did not differ (P>0.05) among the parities. The difference between the fat percentage at the second and fifth parities were 0.28%. On the other hand, the differences for SNF and TS percentages between first and fifth parities were 0.32 and 0.55%, respectively. Consistent with the present findings, Legates (1960) observed a gradual though ire-gular decline in SNF content of milk with advancing age of the cow. Foley et al. (1974) noted that most of the decrease in SNF from first to later lactations was mainly due to decrease in lactose content (a component of SNF) of milk. Yadav et al. (1989) revealed that first and second lactations were having higher SNF percentage compared cond was non significant. The results of the present study are also in agreement with those of Rege et al. (1994) who found a significant effect of parity on butterfat percentage.

It is important to note that there existed a sufficiently large variation in milk constituents among the different genetic groups studied. It was also noted that the difference in milk composition among individuals within breed was substantial. Therefore, within breed selection accompanied by breeding should enormously improve these traits in crossbreds.

Genetic parameters

Variance components and the resulting genetic parameters are presented in Table 3.

Heritability

Heritability estimates of fat percent for Ethiopian Boran and crosses were 0.49 ± 0.03 and 0.32 ± 0.04, respectively. These values are significantly (P<0.01) different from zero. Genetic parameter estimates for milk composition traits in tropics are generally scanty. The estimates of the present study are comparable with report made by Lobo et al. (2000) for tropical dairy animals. However, it is larger than the estimate made for Friesian cattle (0.119) in Kenya by Rege (1991). Other workers (Wilcox et al., 1962; Sharma et al., 1983; Moya et al., 1985; Roman et al., 2000) on the other hand reported a much larger heritability for fat percent.

Estimates of heritability for protein percent were 0.26 ± 0.05 and 0.49 ± 0.03 for Ethiopian Boran and crosses, respectively. These estimates are moderately lower than some of available estimates elsewhere (Wilcox et al., 1962; Sharma et al., 1983; Moya et al., 1985; Roman et al., 2000) but higher than average of literature reports for tropical dairy cattle (Lobo et al., 2000) and thus creates an opportunity for genetic improvement of this trait through selection.

Heritabilities of SNF for Ethiopian Boran and crosses (0.46 ± 0.04 and 0.45 ±0.04, respectively) and estimates of TS (0.39 ± 0.04 and 0.41 ± 0.04, respectively) were lower than literature reports (Wilcox et al., 1962; Sharma et al., 1983; Moya et al., 1985; Roman et al., 2000) as well as average value estimates for tropical dairy cattle by Lobo et al. (2000).

Repeatability

Fat, protein, SNF and TS percentages had high repeatability estimates. The values were 0.98, 0.59, 0.93 and 0.99 respectively (Table 3) for Ethiopian Boran and 0.66, 0.99, 0.78 and 0.83 for crosses, respectively. These values are within the range normally accepted for dairy cattle (Moya, 1977; Sharma et al., 1983; Roman et al., 2000). Rege (1991), however, reported lower than

Table 3. Estimates of variance components, heritability (h^2 ± SE), repeatability (r) and cow effects (c^2 ± SE) for milk composition traits

Estimate[1]	Fat %	Protein %	SNF %	TS %
		Ethiopian Boran		
V_a	105.5	99.9	100.8	101.6
V_c	105.7	123.9	103.3	122.5
V_e	4.8	154.8	16.5	2.9
V_p	216.1	378.6	220.6	226.9
h^2	0.49±0.03	0.26±0.05	0.46±0.04	0.45±0.04
c^2	0.49±0.03	0.33±0.04	0.47±0.04	0.54±0.03
r	0.98	0.59	0.93	0.99
		Crosses		
V_a	100.1	98.8	105.1	100.8
V_c	106.2	102.5	104.6	103.6
V_e	109.2	0.5	58.1	41.0
V_p	315.5	201.8	267.9	245.4
h^2	0.32±0.04	0.49±0.03	0.39±0.04	0.41±0.04
c^2	0.34±0.04	0.50±0.03	0.39±0.04	0.42±0.04
r	0.66	0.99	0.78	0.83

Va, additive genetic variance; Vc, permanent environmental variance; Ve, residual variance and Vp is phenotypic variance

Table 4. Genetic correlations for Ethiopian Boran (above diagonal) and crosses (below diagonal) (±SE) between milk compositions traits

Parameter	Fat %	Protein %	SNF %	TS %
Fat %	-	0.51±0.12**	0.16±0.15 NS	0.92±0.15**
Protein %	0.88±0.11**	-	0.71±0.05**	0.82±0.09**
SNF %	0.67±0.11**	0.92±0.05**	-	0.78±0.06**
TS %	0.92±0.12**	0.85±0.09**	0.99±0.05**	-

**, P<0.01; NS, non significant.

to third, whereas the difference between the first and se- expected repeatability value for butterfat percent (0.37) and suggested genetic parameters of this trait were affected by the large errors associated with butterfat test results during part of the study period.

Genetic correlations

Genetic correlations between milk composition traits for Ethiopian Boran and crosses are presented in Table 4. The genetic correlations among these traits for both genetic groups were generally large and significant (P<0.01) except for correlations between fat and SNF percents. Very strong (0.99 ± 0.05) genetic correlation was estimated between SNF and TS percent in crosses. Literature reports on genetic correlations between milk constituents, especially in tropics, are scanty. However, results of present study concur well with the reports in the literature (Sharma et al., 1983; Lobo et al., 2000; Misra and Joshi, 2004).

Crossbreeding parameters

Results of individual breed additive differences between Ethiopian Boran and Holstein Friesian breed were summarized in Table 5. The estimates for all the milk composition traits were negative and significant (P<0.01). The values were, -1.45 ± 0.18, -0.97 ± 0.19, -1.13 ± 0.3 and -2.47 ± 0.35 for fat, protein, SNF and TS percentages, respectively. Ahlborn-Breier and Hohenbhoken (1991) found an individual additive genetic breed difference between primiparous Holstein Friesian and Jersey cows of 1.2% for milk fat percentage in favor of Jersey.

Individual heterotic effects, as expected, were positive and significant (P<0.01) in improving the milk composition traits (Table 5). Individual heterotic effects accounted for 0.54, 0.25 0.33 and 0.72% differences between mid-parent mean values and first crosses for fat, protein, SNF and TS, respectively. Estimates for heterotic effects on milk composition traits in the tropics are limited. However, Rege et al. (1994) found a similar estimate for butterfat content in a cross involving Jersey and Ghana Shorthorn. Ahlborn-Breier and Hohenbhoken (1991), however, didn't find any individual heterotic effect in

Table 5. Estimates of breed additive (g_iF), individual heterosis (h_iBF) and maternal heterosis (h_mBF) for milk composition traits.

Genetic effect	Fat (%)	Protein (%)	SNF (%)	TS (%)
g_iF	-1.45 ± 0.18**	-0.97 ± 0.19**	-1.13 ± 0.3**	-2.47 ± 0.35**
h_iBF	0.54 ± 0.09**	0.25 ± 0.10**	0.33 ± 0.15*	0.72 ± 0.18**
nth_mBF	0.18 ± 0.11**	-0.06 ± 0.11^{NS}	-0.07 ± 0.18^{NS}	0.11 ± 0.21^{NS}

*,P<0.05; **,P<0.01; NS, Non significant.

Friesian- Jersey crosses for fat percent but did record significant heterotic effect in milk fat yield.

Maternal heterosis in this study is significant (P<0.01) for fat percentage only. Ahlborn-Breier and Hohenbhoken (1991) also reported a significant but very small (0.05%) maternal heterosis for fat percentage in Friesian-Jersey crosses. From the results of estimation of crossbreeding parameters, it should be noted that the genetic effect with the largest influence on all the milk composition traits was additive breed content. The next most important genetic effect was individual heterosis. Maternal heterotic effects were non significant except for fat percent.

Conclusion

Milk constituent values of Ethiopian Boran were found to be higher than the crosses. As the Holstein Friesian exotic inheritance level increased, the constituent values declined. Individual heterotic effects were positive and significant. Generally, it was studied that there existed a sufficiently large variation in milk constituents among the different genetic groups. It was also noticed that the difference in milk composition among individuals within breed was substantial. Therefore, within Ethiopian Boran breed selection accompanied by crossing should enormously improve these traits in crossbreds.

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