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Genetic parameters for early growth traits in a Merino lambs estimated using multitrait analysis

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Abstract

Genetic parameter estimates for birth weight, weaning weight and pre-weaning average daily gain were assessed for Merino lambs maintained at the Tygerhoek Experimental Farm. Random effects fitted were direct and maternal additive genetic effects, and maternal permanent environmental effect. Direct heritability (h^2) estimates of 0.21, 0.40 and 0.40 and maternal heritability (m^2) estimates of 0.27, 0.02 and 0.01 were obtained for body weight at birth, weaning and pre-weaning average daily gain, respectively. The corresponding maternal permanent environmental effects (h^2) were 0.05, 0.02 and 0.01. The genetic correlation estimates between direct and maternal effects were -0.02, -0.10 and -0.16 for birth weight, weaning weight and pre-weaning average daily gain, respectively. Direct genetic correlation estimates between birth and weaning weights and between birth weight and pre-weaning average daily gain were of low to moderate magnitude and positive. However, the direct genetic correlation between weaning weight and pre-weaning average daily gain was almost unity. Maternal genetic correlation estimates among the traits were high and positive. It is concluded that the traits can be improved if selection could be based on either of the traits studied.

Keywords: Early growth; genetic parameter; Merino lamb

Introduction

In mammals, growth is influenced by the genes of the individual for growth, by the environment provided by the dam and other environmental effects (Lewis & Beatson, 1999; Albuquerque & Meyer, 2001). In young animals, the milk supply of the dam (Bradford, 1972; Meyer, 1992; Lewis & Beatson, 1999)

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and the maternal care she provides largely contribute to their growth (Bradford, 1972; Lewis & Beatson, 1999). The dam's genes for these traits affect the environment experienced by the offspring through milk production and mothering ability (Bourdon, 2000). Maternal effects may be expected to be more important in sheep than in cattle because of the greater relative variation in litter size in sheep and the competition between lambs for their mother's milk supply. It incorporates both similarities between twins and similarities between lambs born to the same ewe in different years (Snyman *et al*., 1995). The dam, therefore, contributes to the phenotypic value of her offspring, not only by a sample half of her genes, but also through her genes responsible for the expression of her maternal performance.

The confounding of the maternal effect of the dam and her genetic contribution to the phenotypic value of her offspring and the possibility of a negative genetic correlation between the direct and maternal effect are the two most important problems in selection programmes (Willham, 1980). Thus, in order to decide upon a feasible selection strategy, estimation of the genetic parameters and the correlations between direct and maternal additive genetic effects are necessary. The recent statistical and computational developments have made routine analysis to estimate these parameters by Restricted Maximum Likelihood (REML), fitting an animal model, conceptually straightforward and technically feasible. Further, a multitrait genetic evaluation by best linear unbiased prediction (BLUP) fitting an animal model requires partitioning of the phenotypic variances and covariances into their direct genetic, maternal genetic, maternal permanent environmental and residual components (Meyer, 1993).

The objective of this study was to assess genetic parameters for birth weight, weaning weight and average daily gain to weaning in the Tygerhoek Merino flock using multitrait analysis.

Materials and Methods

Data used in this study were obtained from the Merino flock maintained at the Tygerhoek Experimental Farm. The general management of the flock and description of the study area are as described by Duguma (2001). A total of 8310 lambs born from 2538 ewes and sired by 681 rams, raised over the period from 1970 to 1998 were used in this study. Liveweight at birth (BW), weaning (WW) and preweaning average daily gain (ADG) were the growth traits investigated. To identify the effects to be included in the fixed part of the model, an analysis of variance was performed on birth year (1970 to 1998), sex (male, female), birth type (single, multiple), age of dam (2- to 6-yr old) and group (group of animals selected for increased clean fleece weight and the unselected control). The effects tested were significant ($p < 0.001$) for all traits and hence included in the operational model.

Variance components were estimated by Restricted Maximum Likelihood procedures (REML) applying the VCE 4.2.5 package of Groeneveld (1998). An animal model including maternal additive genetic and maternal permanent environmental effects as additional random effects was fitted for all three traits. By using estimated (co)variance components, direct heritabilities (h^2), maternal heritabilities (m^2), maternal permanent environmental variances (c^2) and the correlations between the direct and maternal additive genetic effects (r_{am}) were obtained. Total heritabilities (h^2_t) were calculated as defined by Willham (1972). All models involved the same fixed effects.

The following model was fitted for all traits:

$y = X\mathbf{b} + Z\mathbf{a} + M\mathbf{m} + P\mathbf{c} + e \quad Cov(a, m) = A\sigma_{am}$

where:

y = the vector of records

b = the vector of fixed effects

X = the matrix that associates **b** with Y

a = the vector of breeding values for direct additive genetic effects

Z = the matrix that associates **a** with Y

m = the vector of breeding values for maternal genetic effects

M = the matrix that associates **m** with Y

c = the vector of permanent environmental effects due to dam

P = the matrix that associates **c** with Y

e = the vector of residual effects.

Further, with **A** the numerator relationship matrix between animals, $\mathbf{I}_n$ an identity matrix with order the number of animals and **I** an identity matrix with order the number of records, the (co)variance structure of the random effects in the analysis can then be described as:

$V(a) = \sigma^2_a\mathbf{A}$, $V(m) = \sigma^2_m\mathbf{A}$, $V(c) = \sigma^2_c\mathbf{I}_n$, $V(e) = \sigma^2_e\mathbf{I}$ and $Cov(a, m) = \mathbf{A}\sigma_{am}$, where σ^2_a is the additive genetic variance, σ^2_m, the maternal additive genetic variance, σ^2_c, the maternal permanent environmental variance, σ^2_e, the residual variance and σ_{am}, the direct and maternal genetic covariance. It was assumed that all effects in the models are independent with the exception of the direct and maternal additive genetic effects.

Results

Estimates of (co)variance components, direct (h^2) and maternal (m^2) heritabilities, values for the maternal permanent environmental effects (c^2) and the correlations between the direct and maternal additive genetic effects (r_{am}) for each trait are shown in Table 1. Standard errors of heritability estimates were unavailable. Estimates of the various correlations between traits are presented in Table 2.

Table 1. Variance components and genetic parameters for BW, WW and ADG estimated in multitrait analysis

Item	**BW**	**WW**	**ADG**
Variance components			
σ^2_a	0.11	8.71	850.67
σ^2_m	0.15	0.33	6.13
σ_{am}	-0.01	-0.17	-11.71
σ^2_c	0.02	0.38	23.06
σ^2_e	0.26	12.98	1264.21
σ^2_p	0.54	22.22	2132.35
Genetic parameters			
h^2	0.21	0.40	0.40
m^2	0.27	0.02	0.01
R_{am}	-0.02	-0.10	-0.16
h^2_t	0.34	0.39	0.39
c^2	0.05	0.02	0.01
e^2	0.48	0.59	0.60

σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ_{am}, direct-maternal genetic covariance; σ^2_c, maternal permanent environmental variance; σ^2_e, residual variance; σ^2_p, phenotypic variance; h^2, direct heritability; m^2, maternal heritability; r_{am}, direct-maternal genetic correlation; h^2_t, total heritability; c^2, ratio of maternal permanent environmental effect; e^2, ratio of residual effect.

The h^2 estimates for body weight varied from 0.21 to 0.40 between BW, WW and ADG with a tendency of an increasing age trend. For BW, maternal additive genetic variance components and heritabilities (m^2) were larger than both the direct additive genetic and maternal permanent environmental effects. However, for WW and ADG, both maternal additive genetic and maternal permanent environmental effects were smaller than the direct additive genetic effects. In all cases, the correlations between direct and maternal additive genetic effects (r_{am}) were nearly zero and negative in sign.

Table 2. Estimated direct genetic, maternal genetic, maternal permanent environmental and residual correlations (above diagonal) and the corresponding covariances (below diagonal) between BW, WW and ADG from multitrait analyses.

Trait	**BW**	**WW**	**ADG**
Direct additive genetic effects			
BW	-	0.16	0.04
WW	0.16	-	0.99
ADG	0.42	85.49	-
Maternal additive genetic effects			
BW	-	0.93	0.60
WW	0.20	-	0.85
ADG	0.57	1.21	-
Maternal permanent environmental effects			
BW	-	0.89	0.82
WW	0.08	-	0.99
ADG	0.60	2.92	-
Residual effects			
BW	-	0.16	0.02
WW	0.30	-	0.99
ADG	0.41	126.83	-

Direct genetic correlations between BW and WW and between BW and ADG were small positive, while that between WW and ADG was almost unity. The maternal genetic correlations between BW and WW, BW and ADG and WW and ADG were all high positive. The maternal permanent environmental correlation estimates between the different weight traits were positive and high.

Discussion

Estimates of h^2 for BW obtained in the present study are within the range of the animal model estimates, which varied from 0.04 (Cloete *et al.*, 1998) to 0.42 (Van Wyk *et al.*, 1993). Estimates of h^2 for WW obtained were also within the literature ranges which varied from 0.09 (Burfening & Kress, 1993) to 0.50 (Fadili *et al.*, 2000). The estimates for ADG ranged from 0.19 (Yazdi *et al.*, 1997) to 0.42 (Fadili *et al.*, 2000). The estimates for all three traits also well correspond to those reported by Heydenrych (1975), which was based on part of the same data set as was used in the present study but using sib analysis. The estimates were also within the range of unitrait estimates reported by Duguma (2001), which was used the same data set.

In the present study, the magnitude of m^2 estimates obtained for BW were substantial, being greater than both the h^2 and c^2 estimates (Table 1). The m^2 estimates, however, were lower than h^2 estimates for WW and ADG. Yazdi *et al*. (1997) found comparable results and indicated that this was presumably due to poor quality of pasture that prevented the genetic ability of ewes to provide sufficient milk for their lambs to be expressed. Thus, inadequate milk yield could mask the expression of the maternal ability of ewes. The value for m^2 obtained in BW was lower than those reported by Burfening & Kress (1993) and Van Wyk *et al*. (1993). These authors reported m^2 estimates ranging from 0.30 to 0.65 depending on the model applied for BW, but without considering the effect of maternal permanent environmental effects. These high m^2 values might have been including effects due to the permanent environmental effects of the dam. It has been indicated by Snyman *et al*. (1995) that the exclusion of the maternal permanent environmental effect, when it has a significant influence, could cause estimates of m^2 to be biased upwards.

The c^2 estimate computed for BW was in general agreement with those reported by Cloete *et al*. (2001). These authors found an estimate of 0.07 for the permanent environmental effect of the dam in BW. It was, however, larger than a zero c^2 estimate reported by Maria *et al*. (1993), but lower than those reported by Snyman *et al*. (1995) and Neser *et al*. (2001). Both Snyman *et al*. (1995) and Neser *et al*. (2001) reported an estimate of 0.12 for the permanent environmental effect of the dam in BW. They ascribed this value to uterine environment provided by the dam and the effect of multiple births. Likewise, Maria *et al*. (1993) indicated that the permanent environmental effect is due to uterine capacity, feeding level during late gestation and the maternal behaviour of the ewe. Maternal behaviour is likely to be associated with the rearing ability of a dam. In the present study, relatively lower c^2 estimates were obtained for WW and ADG. Literature results indicated that early growth of a ewe has an effect on the amount of milk she gives to her lambs during her early life (Gould & Whiteman, 1975).

Generally, results showed a trend of an increasing direct additive but decreasing maternal variance ratios from birth to weaning at 100 days of age. Other studies reported a similar pattern (Maria *et al.*, 1993; Burfening & Kress, 1993; Tosh & Kemp, 1994; Fadili *et al.,* 2000). The increasing h^2 of lamb weight at weaning is most likely caused by an increased expression of genes with direct additive effects on body development (Yazdi *et al.*, 1997). This also confirms the idea of Robison (1981) and Snyman *et al.* (1995), who concluded that maternal effects in mammals diminish with age. In general, results of this study showed that maternal effects, genetic and environmental, are important for BW and need to be considered in any selection programme.

The estimates of correlations obtained between direct and maternal additive genetic effects (r_{am}) for BW are lower than in most of the estimates reported in the literature (Maria *et al.*, 1993; Abegaz & Duguma, 2000; Neser *et al.*, 2001). The estimate of 0.35 reported by Neser *et al.* (2001) for BW opposed the negative estimates found in this study. This same study reported a high negative correlation estimate in WW. In the present study, the signs of these estimates for WW was opposed to those reported by Näsholm & Danell (1996), Snyman *et al.* (1996) and Yazdi *et al.* (1997). They reported positive genetic correlations ranging from 0.18 to 0.57. The very low negative genetic correlations obtained in the present study suggested that selection for increased liveweight of the lamb would not negatively affect the maternal ability of the ewe. Cloete *et al.* (2001) also found no significant correlation between the direct additive and maternal additive effects in Merino flock. According to Meyer (1997) a negative estimate of the direct and maternal additive genetic covariance has mostly been observed in field data while it has by and large been absent in experimental data sets. She has indicated that this could have been attributed to factors like more uniform management and lack of preferential treatment. Alternatively, it may also reflect better identification of contemporary or management groups.

Early growth traits in sheep are mostly characterised by negative r_{am} estimates (Maria *et al.*, 1993; Fadili *et al.*, 2000; Al-Shorepy, 2001; Neser *et al.*, 2000; 2001). These estimates may be considerable and could be affected by small data sets (Maria *et al.*, 1993; Fadili *et al.*, 2000; Al-Shorepy, 2001), the models fitted or poor pedigree structure that is inadequate for obtaining estimates of both direct and maternal heritabilities and the genetic correlations between animal effects (Kominakis *et al.*, 1998; Lee *et al.*, 2000).

The effects of management practices on the direct and maternal genetic correlations have also been indicated. Both Meyer (1992) and Swalve (1993) suggested that environmental covariances between dam and offspring that is not accounted for may bias the direct and maternal genetic correlation downwards. The difficulty of statistically separating the direct and maternal component (Meyer, 1992), and the design of fixed effects were also suggested as a factor that could have a strong influence on the reliability of the estimation of the direct and maternal additive genetic correlation (Gerstmayr, 1992). In beef cattle, Robinson (1996) indicated that the negative correlation between direct and maternal genetic variances could result from other effects in the data rather than a true negative genetic relationship.

Genetic correlations between growth traits of the Tygerhoek Merino lambs were positive and varied from low to high. In his extensive review, Fogarty (1995) reported a weighted average genetic correlation estimate between BW and WW of 0.39. The low direct genetic correlations between BW and WW might be beneficial for avoiding lambing difficulties, which could result in loss of lambs and dams. A significant reduction in survival rate of lambs was observed in this flock as lambs became heavier at birth (Duguma, 2001).

Conclusions

Heritability estimates of early growth traits ranged from moderate to moderately high and showed a trend for increasing direct additive and decreasing maternal variance ratios from birth to weaning at 100 days of age. Estimates of direct genetic correlatons between WW and BW were low, indicating that selecting for WW may not result in lambing difficulties. The genetic antagonisms between direct and maternal additive genetic effects obtained were also not large enough to prevent genetic improvement if selection is based on individual weight performance.

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Multitrait Estimates of (Co)Variance Components and Genetic Parameters of Preweaning Growth Traits in a Multibreed Beef Cattle Herd

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Abstract

Variance components and resulting genetic parameters of birth weight (BWt), weaning weight (WWt) and average daily gain (ADG) in a multibreed beef cattle population were estimated by Restricted Maximum Likelihood (REML) procedures based on 4117 records. Four multitrait animal models were fitted including a simple model with the animal direct effects as the only random effect and another model allowing for both genetic and permanent maternal environmental effects. The model that included direct genetic and permanent maternal environmental effects generally best described the data analysed. The simple model ignoring maternal effects most likely inflated direct heritability estimates. Direct heritability estimates were 0.11, 0.19, and 0.15 for BWt, WWt and ADG, respectively using a model comprised both the genetic and maternal environmental effects. Maternal heritabilties were low under both Model 3 (accounted for direct and maternal genetic effects) and 4 (direct and maternal genetic and permanent maternal environmental effects), ranging from 0.02 to 0.26. Permanent maternal environmental effects were the important factor sdetermining WWt and ADG. Direct and maternal genetic correlations ranged from 0.42 to 0.44 (BWt), -0.22 to -0.25 (WWt) and -0.17 to -0.23 (ADG).

Keywords: Beef cattle, preaweaning traits, direct heritability, maternal heritability, total heritability, genetic correlation

Introduction

The potential for genetic improvement in economically important traits of beef cattle in a selection programme depends on the extent of the genetic variation, heritability and sign and magnitude of genetic correlations of the traits considered. Several estimates of maternal heritabilities and direct-maternal genetic correlations in the past have been obtained by calculating variance component estimates from sire-maternal-grand-sire and sire-dam models analyses (Quaas, *et al* 1985; Trus and Wilton, 1988; Brown *et al.*, 1990; Wright *et al.*, 1991). However, owing to the recent increased computing power available, linear models are employed in the genetic evaluation of animals separating direct genetic, maternal genetic and maternal permanent environmental effects, using animal models (Mackinnon *et al.*, 1991; Meyer, 1992a; Swalve, 1993; Robinson, 1996b; Schoeman and Jordaan, 1999). In general, the animal model is considered the preferred model for a wide range of applications. A number of investigations applied this methodology for unitrait analysis of early growth traits of beef cattle, but, to date, limited estimates have been reported from corresponding multitrait analyses for multibreed beef cattle.

Genetic parameters for the traits of interest are a characteristic of the population in which they are estimated. Their estimates vary widely between authors, years, methods of estimation, breeds and production systems (Mohiuddin, 1993; Swalve, 1993; Koots *et al.* 1994a; b; Robinson, 1996a). The objective of this work therefore was to estimate (co)variances, heritabilities and genetic correlations for preweaning growth traits in a multibreed beef cattle by separating direct genetic, maternal genetic and maternal permanent environmental effects fitting multitrait animal models.

Materials and Methods

Data were obtained from multibreed beef calves born and raised on the Johannesburg Metropolitan Council's farms during the period of 1968 to 1992. The beef herds have been kept on two farms, *viz.* the Olifantsvlei farm and the Northern farm, which are located in the Gauteng province of South Africa. The beef herds are raised on a restricted pasture feeding system using irrigated annual and perennial rye grass pastures supplemented with *Eragrostis curvula* hay, maize meal, distillers grain and silages of maize, sorghum and grass (Paterson *et al.*, 1980) when necessary. Breeding systems, animal management and selection procedures of the herd were described in detail by Schoeman and Jordaan (1999).

Birth weight, birth date, weaning weight and weaning date as well as breed identity were recorded for each individual calf born during this period. Breed identity of each animal was established by tracing pedigrees back to the base population. Cows calved almost throughout the year; however, the majority (67%) of calves were born in winter (June - October). Hence, season of birth was recorded as either "summer born" or "winter born". After editing the data by removing extreme values of weights and calves with unknown parents, 4119 records were available for analysis. The records included birth weight (BWt), weaning weight (WWt) and pre-weaning average daily weight gain (ADG). The characteristics of the dataset are presented in Table 1.

Table 1 Characteristics of the data set for BWT, WWt and ADG (birth to weaning) of calves.

	Number of records	**Minimum**	**Maximum**	**Mean**	**Standard deviation**
Birth weight (kg)	4119	22.00	55.00	35.80	6.20
Weaning weight (kg)	4119	102.00	358.00	192.40	34.89
Average daily gain (kg)	4119	0.28	1.92	0.75	0.14
Calf age at weaning (days)	4119	106.00	310.00	210.70	26.90
Dam age at parturition (years)				5.64	2.30
Number of calves/sire				56.40	
Number of calves/dam				2.10	

Statistical procedures

First the data set was analysed using the General Linear Model (GLM) procedures of the Statistical Analysis Systems (SAS, 1996). The variables fitted included the fixed effects of dam age (4 levels), genotype of calf (58 levels), sex of calf (2 levels) and herd-year-season (66 levels). Weaning age of calf was included as a covariate for WWt. All fixed effects and their interactions that had no (P>0.05) influence on BWt, WWt and ADG were excluded from the final analysis using the step down eliminationprocedure.

Estimates of (co)variance components from and multitrait analyses were then performed by using the REML VCE packages of Groeneveld (1996, 1997), fitting four animal models. Model 3 and 4 allowed for a covariance between direct and maternal genetic effects. These models in matrix notation were:

Model 1: $Y = X\mathbf{b} + Z_1\mathbf{a} + \mathbf{e}$

Model 2: $Y = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{c} + \mathbf{e}$

Model 3: $Y = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + \mathbf{e}$

Model 4: $Y = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + Z_3\mathbf{c} + \mathbf{e}$

Where :

Y = a vector of the calf's record for each trait.

X = a known incidence matrix relating the observations to the fixed effects.

b = a vector of fixed effects

Z_1, Z_2 and Z_3 = known incidence matrices relating the observation (Y) to the unknown random effects of **a, m** and **c.**

a = denotes a random vector for the animals own additive genetic effects.

m = a random vector of maternal additive genetic effects

c = a random vector of permanent maternal environmental effects

e = a vector of random residual errors.

It is furthermore assumed that:

Var (**a**) = $\mathbf{A}\sigma^2_{\mathbf{a}}$, Var (**m**) = $\mathbf{A}\sigma^2_{\mathbf{m}}$, Var (**c**) = $\mathbf{I}\sigma^2_{\mathbf{c}}$, Var (**e**) = $\mathbf{I}\ \sigma^2_{\mathbf{e}}$, Cov (**a,m**) = $\mathbf{A}\sigma_{\mathbf{am}}$

Where, **A** = the numerator relationship matrix between the animals

$\sigma^2_{\mathbf{a}}$ = the direct additive genetic variance

$\sigma^2_{\mathbf{m}}$ = the maternal additive genetic variance

$\sigma^2_{\mathbf{c}}$ = the variance of maternal permanent environmental effects

$\sigma^2_{\mathbf{e}}$ = the variance of residual error

σ_{am} = the genetic covariance between direct and maternal genetic effects

I = an identity matrix.

Heritabilities were estimated as follows: (a) Heritability for the direct additive genetic effects, $h^2_a = \sigma^2_a / \sigma^2_p$, where σ^2_p is the phenotypic variance; (b) Heritability for the maternal genetic effects, $h^2_m = \sigma^2_m / \sigma^2_p$; (c) Total heritability, $h^2_T = [\sigma^2_a + 0.5\sigma^2_m + 1.5\sigma_{am}]/\sigma^2_p$, (Willham, 1972). The genetic correlation between direct and maternal genetic effects was estimated by:

$r_{am} = \sigma_{am} / (\sigma^2_a\ \sigma^2_m)^{1/2}$

Result and Discussions

Estimates of (co)variance components and total heritabilities (h^2_T) are presented in Table 2 while estimates of h^2_a, h^2_m, permanent maternal environmental effect (c^2), direct genetic correlations and maternal genetic correlations are presented in Table 3 for BWt, WWt and ADG from multitrait analysis. Estimates of heritabilities for all traits agreed with the values in the literature summarised by Meyer (1992a), although the estimates reported varied according to the differences in type of records analysed (Wright *et al.*, 1987), methods of estimation (Nelsen *et al.*, 1986) and models used for the analysis (Mohiuddin, 1993). According to log likelihood value (Groeneveld, 1996; 1997) Model 2 provided a better fit to the data for all traits. The h^2_T estimates varied from 0.15 to 0.59. Total heritability estimates for the traits lie within the range of literature estimates of Mohiuddin (1993), which vary from –0.02 to 0.68 for BWt and from 0.02 to 0.81 for WWt. Estimates of h^2_T for ADG also correspond with literature estimates reported in the review of Meyer (1992a).

Table 2 Estimates of (co)variance components (kg²) and total heritabilities (h^2_T) of BWt, WWt and ADG.

	Parameters						
Model	σ^2_A	σ^2_m	σ_{am}	σ^2_C	σ^2_e	σ^2_p	h^2_T
				Birth weight			
Model 1	15.03				10.41	25.44	0.59
Model 2	5.79			3.49	13.89	23.17	0.25
Model 3	2.40	3.37	1.24		15.70	22.71	0.26
Model 4	2.57	2.37	1.02	1.25	15.47	22.68	0.23
				Weaning weight			
Model 1	346.64				331.10	677.74	0.51
Model 2	114.24			137.84	376.81	628.89	0.18
Model 3	114.93	158.95	-29.27		389.09	633.70	0.26
Model 4	119.18	21.61	-12.58	128.31	372.65	629.17	0.18
				Average daily gain			
Model 1	0.007				0.007	0.014	0.48
Model 2	0.002			0.003	0.008	0.013	0.15
Model 3	0.002	0.003	0.000		0.009	0.014	0.25
Model 4	0.002	0.000	0.000	0.003	0.008	0.013	0.15

σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ_{am}, direct-maternal genetic covariance; σ^2_c, maternal permanent environmental variance; σ^2_e, error variance; σ^2_p, phenotypic variance; h^2_T, total heritability.

The direct heritabilities (h^2_a) were high under Model 1, while they were low to medium under the alternative models (Table 3). The exclusion of the maternal effects most likely inflated h^2_a for all traits. The results of Model 1 that yielded high heritabilities in this study agree with Mackinnon *et al.* (1991) who reported h^2_a estimates of 0.78 (BWt), 0.56 (WWt) and 0.50 (ADG) in tropical cattle when fitting a model accounting for direct genetic effects only. Schoeman and Jordaan (1999) found h^2_a estimates of 0.62 for BWt and 0.52 for WWt in the same multibreed beef cattle herd but using a different subset of the data and fitting a multitrait animal model, which accounted for direct effects only. To assess this potential bias in the present study, either a maternal permanent environmental effect (Model 2) or maternal additive genetic effect (Model 3) or both (Model 4) were included in the models, and the resultant h^2_a estimates were considerably reduced (Table3).

The present estimates of h^2a for BWt and WWt were lower than the unweighted means reported by Koots *et al.* (1994a) for BWt (0.35) and WWt (0.27) when fitted to Models 2, 3 or 4.

The direct genetic correlations (r_g**) (**Table 3) varied from 0.37 to 0.97 for the traits, indicating a medium to high genetic association between them. The corelation between the direct genetic components of BWt and WWt were larger than those between BWt and ADG under all the models. The correlations between WWt and ADG for the different models were high and almost unity. Although the correlations between the traits were all positive, differences were observed in estimates between the models. As indicated by Meyer (1992b), the differences in estimates between the different models may be related to the inclusion of environmental covaraince s or possible negative sampling correlations and large sampling errors**.** Mackinnon *et al.* (1991) Reported direct genetic correlations between BWt and WWt, BWt and ADG, and WWt and ADG of 0.43, 0.24 and 0.94, respectively. Likewise, Koots *et al.* (1994b) reported similar mean positive genetic correlations between BWt and WWt (0.50) and BWt and ADG (0.26). The results of this study as well as those in the literature suggest that selection for higher WWt or ADG would increase BWt, which may be associated with dystocia and loss of productivity. Because of such genetic relationships, other selection criteria should be sought when the objective is to increase WWt without adversely affecting BWt in such a herd. For example, Schoeman and Jordaan (1999) suggested an index of cow efficiency as the best appropriate selection criteria when the aim is to improve WWt without a corresponding increase in BWt.

Maternal heritabilities (h^2_m) varied from 0.02 in Model 4 to 0.26 in Model 3 (Table 3). The inclusion of the maternal environmental effect (c^2) in Model 4 reduced the h^2_m estimates for all traits compared to estimates with Model 3. However, in the study of Schoeman and Jordaan (1999), the inclusion of c^2

had almost no effect on h^2_m estimates of pre-weaning related traits, except for pre-weaning relative growth rate. These estimates are in agreement with the results of Mostert *et al.* (1998) who found h^2_m estimates of 0.06 to 0.15 for BWt and 0.08 to 0.19 for WWt fitting a multitrait model accounting for both direct and maternal effects in five beef cattle breeds in South Africa. Koots *et al*. (1994a) also reported a weighted mean h^2_m of 0.14 for BWt and 0.13 for WWt.

Maternal genetic correlations (Table 3) were all positive, and ranged from a low of 0.04 between maternal components of BWt and ADG to a high of 0.99 between WWt and ADG. Apart from the correlation between WWt and ADG, all these maternal correlations were lower than the corresponding direct genetic correlations. Generally, the maternal genetic components of related traits are expected to be positively correlated. The correlation between BWt and WWt obtained from Model 4 is in agreement with those of Swalve (1993) who estimated maternal genetic correlations ranging from 0.30 to 0.83 in the Australian Simmentaler beef cattle. The Model 3 estimate of this parameter was somewhat lower than the weighted mean value in literature of 0.39 between BWt and WWt but agree with the value from Model 4 (Koots *et al*., 1994b). The correlation between maternal effects for BWt and WWt reported by Rust *et al*. (1998) was 0.24 for the Semmentaler cattle population in South Africa.

The maternal permanent environmental effect (c^2) slightly varies between Models 2 and 4 for BWt, but was almost similar for WWt and ADG (Table 3). For BWt (Model 4), h^2_m tended to be slightly higher than c^2. This is in agreement with previous findings of Meyer (1992a, 1993b) for Hereford and Angus beef cattle and Swalve (1993) for Simmentaler. Maternal heritabilities were lower than c^2 for WWt and ADG (Model 4). The results correspond with the estimates of Waldron *et al.* (1993) and Meyer (1993a) but varied from the reports of Bertrand and Benyshek (1987), Swalve (1993) and Schoeman and Jordaan (1999). Estimates of c^2 have tended to be higher in most studies using field data, like in this study. For instance, in Polled Hereford and Charolais field data Meyer (1993a; b) estimated c^2 for WWt from animal model to be 0.22 and 0.23, whereas h^2_m estimates were 0.10 and 0.04, respectively. The maternal permanent environmental effect plays an important role in the preweaning growth traits of this beef cattle population.

Table 3. Estimates of direct heritabilities (h^2_a) (left, on diagonal) and maternal heritabilities (h^2_m) (right, on diagonal) and permanent maternal environmental effect (c^2) (right, on diagonal in bracket), direct genetic correlations (left, above diagonal), maternal genetic correlations (right, above diagonal) from multitrait analyses of BWt, WWt and ADG fitting different animal models.

	Direct components			**Maternal components**		
	BWt	**WWt**	**ADG**	**BWt**	**WWt**	**ADG**
BWt						
Model 1	**0.59**	0.55	0.37			
Model 2	**0.25**	0.76	0.58	(0.15)*		
Model 3	**0.10**	0.69	0.49	**0.14**	0.17	0.04
Model 4	**0.11**	0.69	0.48	**0.10** (0.05)	0.41	0.22
WWt						
Model 1		**0.51**	0.97			
Model 2		**0.18**	0.96		(0.22)	
Model 3		**0.19**	0.96		**0.26**	0.99
Model 4		**0.19**	0.95		**0.04** (0.21)	0.98
ADG						
Model 1			**0.48**			
Model 2			**0.15**			(0.22)
Model 3			**0.14**			**0.21**
Model 4			**0.15**			**0.02** (0.23)

* Permanent maternal environmental effect

Table 4. Correlations between direct genetic and maternal genetic effects and cross-correlations for BWt, WWt and ADG fitting Model 3 and 4.

	Traits	**Direct genetic effect**		
		BWt	**WWt**	**ADG**
	BWt			
	Model 3	**0.44**	0.72	0.78
	Model 4	**0.42**	0.77	0.84
Maternal	WWt			
Genetic effect	Model 3	-0.12	**-0.22**	-0.12
	Model 4	-0.23	**-0.25**	-0.11
	ADG			
	Model 3	-0.15	-0.26	**-0.17**
	Model 4	-0.35	-0.43	**-0.23**

The correlation between the direct genetic and maternal genetic effects (r_{am}) and cross-correlations among traits are presented in Table 4. These correlations were positive for BWt but negative for WWt and ADG. These estimates for BWt were larger than literature reports of Mohiuddin (1993), but correspond with the reports of Trus and Wilton (1988) who reported r_{am} of 0.55 for Shorthorn cattle. The negative r_{am} values estimated for WWt and ADG are consistent with those reported by Trus and Wilton (1988) and Swalve (1993), but lower than the estimates of Mostert *et al.* (1998), Rust *et al.* (1998) Robinson (1996a) and Meyer (1993b) reported for WWt.

The off-diagonal components of the correlation matrix in Table 4 show the correlations between the direct genetic effect of one trait and the maternal genetic effect of another trait or *vice versa* (cross-correlation). The correlation estimates between the direct genetic effect of BWt and maternal genetic effect of WWt (Model 3) agreed well with the average literature estimate of -0.12 (Koots *et al*., 1994b). The estimate from Model 4 was stronger and negative than this average, but lie within the range of –0.20 to –0.58 estimated by Mostert *et al*. (1998). On the other hand, the correlation between the maternal genetic effect of BWt and the direct genetic effect of WWt was very strong and positive (Model 3 =0.72, Model 4 =0.77) compared to the average value of –0.07 reported by Koots *et al*. (1994b). Likewise, the direct genetic effect of BWt was negatively correlated with the maternal genetic effect of ADG and the maternal genetic effect of BWt was positively correlated with the direct genetic effect of ADG. The reason for this difference is not obvious. The correlation between direct or maternal genetic effects for WWt and maternal or direct genetic effects for ADG were both negative. Selection for direct breeding values of WWt and ADG would thus increase maternal breeding values of BWt, while selection for increased maternal breeding values of WWt and ADG would tend to decrease direct breeding values for BWt.

Conclusion

Models for analysis of genetic parameters of early growth traits need to include maternal effects. Estimates of heritabilities from a simple animal model tend to be larger than in most comparable studies, although large genetic variation in this multibreed herd may also be a reason for fairly high heritabilities. The magnitude of heritability estimates indicated that opportunity exists to improve these traits through selection. Maternal permanent environmental effects turned out to be more important than maternal genetic effects for weaning weight and average daily gain.

In the future, similar traits of economic importance such as cow efficiency and carcass traits should also be evaluated in a similar way, although such traits are not expected to be as related to maternal attributes as for the preweaning traits investigated in this study. Despite the fact that multitrait animal model analyses are computationally demanding, they are the most appropriate way of estimating (co)variance components and genetic parameters of growth traits.

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Estimation of crossbreeding parameters for milk production traits of crosses between Holstein Friesian and local Arsi breed in the highland of Ethiopia

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Abstract

Data on milk production from crossbreeding experiment of Holstein Friesian and Local Arsi breed in highland of Ethiopia was used to estimate breed additive, heterosis and recombination effects for individual and maternal traits of average daily milk yield and milk yield per day of calving interval. The least square analysis of variance was used, for evaluation of the various breed groups, and the multiple regression analysis to estimate the contribution of individual and maternal breed additive, heterosis and recombination effects. The effect of Breed group ($p<0.001$) and Parity ($p<0.001$) were significant for both traits, while, season and year group (period) of calving were not significant ($P > 0.05$). Estimated least square means were highest for 50% F1 cross with 6.00 kg for milk/LL and 5.53 kg for milk/CI and lowest for Arsi breed with 3.11 kg of milk/LL and 1.99 of milk/CI. The individual breed additive genetic and heterosis effects were significant for both traits ($P<0.01$). Maternal heterosis and recombination effect were not significant ($P>0.05$) for both traits. The individual breed additive effect was estimated at 3.63 kg milk /day for milk/LL and 2.98 kg milk /day for milk/CI. Individual heterosis effect was 1.08 kg/day (22%) for daily milk yield and 1.48 kg milk/day (45%) for milk/CI. Estimate of individual recombination effect was negative for both traits 0.54 kg/day for milk/LL and 2.75 kg milk/day for milk/CI. The maternal heterosis effects were estimated to be –0.28 kg milk/LL and 0.88 kg milk/CL, while, maternal recombination effect of –1.11 kg/day milk/LL. On the basis of predicted result milk yield increased as proportion of Holstein Friesian inheritance increased up to 50% (F1), and declined from 65.5% to 87.5% and increased above this level. It can be concluded that about equal proportion of genes from the two breeds was optimum.

Keyword: Crossbreeding, Breed additive, Heterosis, Milk yield, Cattle.

Abbreviations: Number of records (N) local Arsi breed (L), Holstein Friesian (F). G^I= Individual additive genetic effect, H^I= individual heterosis effect, G^M= maternal additive genetic effect, H^M= maternal heterosis effect, R^I= individual recombination effect, R^M= maternal recombination effect, Lactation length (LL), Calving interval (CI).

Introduction

Although Ethiopia has large number of indigenous cattle population, their potential for milk production is rather low. At the same time the adaptability of temperate cattle is poor, though their milk yielding capacity is generally good. Crossbreeding between indigenous and temperate cattle where the adaptability of indigenous cattle is combined with high production capacity and good temperament of temperate cattle is considered as the best option to increase milk production. Because of this breed improvement efforts in Ethiopia have so far been limited to crossing zebu with temperate cattle and conduction research to make sound decisions concerning the appropriate level of temperate inheritance (Kiwuwa et al. 1983, Kebede, 1992).

In crossbreeding herds, improvement can be effected by two methods: (1) maximising heterosis and heterosis retention through optimal use of breed combinations and breeding systems, and (2) through utilisation of additive genetic values of the component breeds. In both methods the challenge is to separate the additive and non-additive contribution and partition of the later into within-locus (dominance) and between-locus (epistatic) contributions. In this study data from crossbreeding program in a herd located in highland Ethiopia (Asella station) were used to estimate crossbreeding parameters for average daily milk yield and milk yield per day of calving interval, to identify an optimal breed combination which provides an optimal performance.

Material and Methods

Herd description

Data for this study were obtained from herd at Asella station that is situated 180 km south east of Addis Ababa in a highland plateau of Ethiopia. Chilalo Agricultural Development Unit (CADU) established the herd during 1967. In 1968, crossbreeding in Asella station was started using 200 Arsi, 22 Fogera, 16 Barca and 10 Boran cows purchased from local markets. These cows were mated with pure Holstein Friesian bulls to produce F_1 heifers. The F_1 were later be upgraded to produce 50%, 75%, 87.5% and 93.75% Friesian level. These breeds were also inter se mated with bull of similar blood level. Most mating was by Artificial insemination (AI) using semen from Ethiopian National Artificial insemination Centre.

Only the Friesian * Arsi data are used in this study. The Arsi breed seems to have evolved from the large group of small Abyssinian Short-horned Zebus. They are found the central highlands of Ethiopia, especially in Arsi, east

Shewa and Bale zones. The Arsi cattle are small, short and compact, and are thickset but relatively well proportioned. They are extremely active but temperamental and often very aggressive with an average height at withers of 110 cm live weight is 257 kg and the average carcass yield is 57.4%.

Data collection

Data on 346 records on milk yield and 290 records on calving interval on Local Arsi and Holstein Friesian cross from Asella dairy cattle breeding program was collected and used for this study. Individual records were collected for each cow and each calving. These include breed group, cow number, sire of cow, dame of cow, date of calving, date of dry-off and total lactation milk yield. From these data milk yield per lactation length and milk yield per day of calving interval were analysed. Milk yield per day of lactation length was computed as total lactation milk yield (kg) divided by lactation length (days). Milk yield per days of calving interval was computed as total lactation milk yield (kg) divided by calving interval (days). Calving interval (days) for each lactation was computed as the difference between at start of lactation and next calving. Lactation length (days) was computed as difference between date of start of milking and dry-off date.

A number of factors were identified in the preliminary screening of data that had a bearing on the techniques to be used. The first problem was, the non overlapping years of calving between local Arsi breed and different crossbreds

There was also some deviant observation presented in some of the breed groups, for example very short or long lactations. In the main analysis, these records with lactation length < 200 or greater than 1000 days were discarded in order to avoid possible aberrant results.

Climate

Asela station is located about 180 km southeast of Addis Ababa in the Arsi Region in a highland plateau area rising to a height of 2000-3000 m. Both Arsi Region and Asela station are characterised by mild subtropical weather with maximum and minimum temperatures ranging from 18 to 28 ^{0}C and 5 to 10 ^{0}C, respectively. The station experiences bimodal rainfall, with an annual average precipitation of 1300 to 1350 mm. Short rains occur during March and April, followed by long rains during July to September. The long dry season lasts from November to February, and a short dry spell is experienced in March and June (Kiwuwa et al., 1983).

Herd management

The feeding practice, which varied over the years, was designed to give continuous growth using a moderate plane of nutrition. Natural grazing and concentrate supplement constituted the major feed supply. During dry season hay or concentrates (48% Niger seed cake, 48% wheat bran, 3.5% bone meal and 0.5% salt) were fed to all animals at the rate of 2 to 4 kg per cow per day, depending on the levels of milk yield.

Cows were hand milked twice daily. Newborn calves were taken away from their mothers shortly after birth. They were bucket fed to weaning which occurred between 49 and 79 days. Colostrums and whole milk substitutes were fed to calves twice daily at a rate of 1.0 kg to 2.5 kg milk equivalent per day. Animals were routinely vaccinated against anthrax, rinderpest, blackleg and pleuropneumonia. Regular dosing against internal parasites and measures against mastitis were undertaken. Milk recording was initially carried out daily, but in 1973 was changed to either twice monthly or once every 3 weeks. Vaccinations and treatments against identified ailments were recorded. No individual supplementary feeding records were kept, except for the animals in feeding trials.

Statistical analysis

Data collected from 1968 to 1995, on milk yield/LL and milk yield/CI were analysed using General Liner Model (GLM) of SAS (1987). Two different methods were used in data analysis (Method 1 and method 2), Method 1, the least square analysis of variance was used to compare among breed group, and method 2, the multiple regression analysis to estimate the contribution of breed additive, heterosis and recombination effects. In the first method, the effects included in the model were breed group (12), lactation number (5), season (5) and year group or period of calving (7). Based on result of level of significance from preliminary analysis of the effect of year of calving on milk yield, years of calving were grouped into 7 periods. These period one from 1968 to1971, period 2 from1972-75, period three from 1976-79, period four from 1980-84, period five 1985-89, period six from1990-94 and period seven from1995-1997. For evaluation of the effect of seasons on milk production and calving intervals the months of calving were grouped into five seasons, first part of dry season from October to December, second part of dry season from January to February, short wet season from March to May, first part of wet season June to July and second part of wet season from August to September (Kiwuwa, et al, 1983).

Model one: The statistical model for analysing milk yield/LL and milk yield/CI will be:

$y_{ijklm} = M + L_i + S_j + P_k + B_l + e_{ijklm}$

where:

y_{ijklm} = Lactation milk yield, lactation length or calving interval of an individual animal with

lactation i, in season j, year groups k of breed group l

M = overall mean

L_i = the effect due to the i^{th} lactation number (i = 1...5 for milk/LL and milk/CI)

S_j = the effect due to j^{th} season of calving (j = 1, 2, 3, 4 and 5).

P_k = the effect due to the k^{th} year group of calving (k = 1...7)

B_l = the effect due to the B^{th} breed group (l = 1...12)

e_{ijklm} = random error effect.

Due to many empty cell interaction effects were not evaluated

Model two: The multiple regression approach developed by Robinson et al. (1980) was used (Method 2) to estimate the contribution of breed additive genetic and heterosis effects to differences among breed groups with respect to average milk yield/LL and milk yield/CI.

$y_{ijkl} = M + L_i + S_j + P_k + g^I{}_F X_1 + h^I X_2 + g^M{}_F X_3 + h^M X_4 + R^I X_5 + R^M X_6 + e_{ijkl}$

Where:

y_{ijkl} = Lactation milk yield, lactation length or calving interval of an individual animal with lactation i, in season j, year groups k of breed group l

M = intercept (general level of local Arsi breed)

$g^I{}_F$ = individual genetic effect of Holstein as deviation from local breed.

h^I = individual heterosis effect.

$g^M{}_F$ = maternal additive genetic effect of Holstein as deviation from local breed.

h^M = maternal heterosis effect.

R^I = individual recombination effect.

R^M = maternal recombination effect.

X_1 = proportion of genes from Holstein.

X_2 = proportion of maximum individual heterosis.

X_3 = proportion of genes from Holstein in dam.

X_4 = proportion of maximum maternal heterosis.

X_5 = proportion of maximum individual recombination effect.

X_6 = proportion of maximum maternal recombination effect.

For definition of L, S and P see model 1.

The proportions of Holstein Friesian genes, individual and maternal heterosis, individual and maternal recombination effect (x_1 to x_6) were considered as continuous variables in method 2, for values of X1 to X6 of the different breed groups see Table 1.

Table 1. Proportion of expected additive, breed content in the breed combination with local Arsi breed.

Group	Breed combination {sire}{dam}	N	G^I_F	H^I_{LF}	G^M_F	H^M_{LF}	R^I_{LF}	R^M_{LF}
1	{L}{L}	63	0.0	0.0	0.0	0.0	0.0	0.0
2	{F}{L}	14	0.5	1.0	0.0	0.0	0.0	0.0
3	{F*L}{F*L}	13	0.5	0.5	0.5	1.0	0.5	0.0
4	{L}{F*L}	17	0.25	0.5	0.5	1.0	0.25	0.0
5	{F}{F*L}	42	0.75	0.5	0.5	1.0	0.25	0.0
6	{F(F*L)}{F(F*L)}	7	0.75	0.375	0.75	0.5	0.375	0.25
7	{F}{L(F*L)}	16	0.625	0.75	0.25	0.5	0.1875	0.25
8	{F}{(F*L)(F*L)}	14	0.75	0.5	0.5	0.5	0.25	0.50
9	{F}{F(F*L)}	22	0.875	0.25	0.75	0.5	0.1875	0.25
10	{F}{F[(F*L)(F*L)]}	7	0.875	0.25	0.75	0.5	0.1875	0.25
11	{F}{F[F(F*L)]}	5	0.9375	0.125	0.875	0.25	0.109375	0.1875
12	{F}{[F(F*L)][F(F*L)]}	9	0.875	0.25	0.75	0.375	0.1875	0.375

N=Number of records; L= local Arsi breed; F= Holstein Friesian; GI= Individual additive genetic effect, HI= individual heterosis effect, GM= maternal additive genetic effect, HM= maternal heterosis effect, RI= individual recombination effect, RM= maternal recombination effect.

Results and Discussions

The non genetic environmental effects

The analysis of variance for the traits considered (Model 1) indicated that all effects except season and year group (period) of calving were significant ($p<0.001$) on average daily milk yield/LL and milk yield/CI ($P<0.05$). Result on mean separation (mean contrast) indicated that first and second lactation yields (Milk/LL) were significantly lower, and fifth lactation yields were significantly higher than other lactation yields. Hirooka & Bhutyan (1995) reported similar large significant effects of lactation number and season of calving on average daily milk yield in a cross of Friesian with local tropical breed. The non-significant effect of season of calving was unexpected result. This suggests that even in the tropics, the influence of climatic conditions may be negligible under good management, while age differences (differences of lactation number) are important non-genetic source of variation in milk yield.

Genetic (breed group) effect

Table 2 contains the least square means for breed group. Breed group effect was highly significant for both traits. Although there is no consistent trend, estimated least square means of milk yield per lactation length increased continuously as proportion of Holstein Friesian increased up to (1/2 (F_1) for Milk/LL and up to ¾ (F1) for Milk/CI and above these level a slight decline were observed. A similar decline was observed by Reis (1977) for level of *Bos Taurus* inheritance above 1/2 to 5/8. However, Mason and Buvanendran (1982) reported high milk yield by exotic breed in the seasonally hot climate in the tropics when the animals were well feed and managed.

Table 2. Least Square Means (LSM) and Standard error (SE) of mean by breed group for daily milk yield (milk/LL) and milk yield per day of calving interval (milk/CI)

Breed group	% of HF	Milk/LL			Milk/CI		
		n	Mean	SE	N	Mean	SE
{L}{L}	0	63	3.11	0.46	24	1.99	0.91
{F}{L}	0.5 (F1)	25	6	0.281	20	5.31	0.44
{F*L}{F*L}	0.5 (F2)	21	4.60	0.399	10	3,81	0.75
{L}{F*L}	0.25	22	4.00	0.414	7	4.33	0.95
{F}{F*L}	0.75	71	5.70	0.292	40	5.20	0.49
{F(F*L)}{F(F*L)}	0.75	11	5.54	0.486	6	4.93	0.87
{F}{L(F*L)}	0.625	43	5.00	0.317	29	4.31	0.53
{F}{(F*L)(F*L)}	0.75	17	5.65	0.425	5	4.73	0.95
{F}{F(F*L)}	0.875	36	5.57	0.354	15	4.98	0.74
{F}{F[(F*L)(F*L)]}	0.875	18	5.60	0.425	10	4.38	0.77
{F}{F[F(F*L)]}	0.9375	5	5.73	0.663	-	-	
{F}{[F(F*L)][F(F*L)]}	0.875	8	5.74	0.541	-	-	

L=Local, F=Holstein Friesian, n = Number of observation, SE and Standard error

Crossbreeding parameters

Estimates of G^{I}_{F}, H^{I}_{FL} $H^{M}_{FL,}$ R^{I}_{FL} and R^{M}_{FL} effects are shown in Table 3 for both traits. The individual breed additive difference between Local Arsi and Holstein Friesian breed was highly significant for both traits (p<0.01). The pure Holstein Friesian breed produced about 3.63 ± 0.52 kg more milk/day for milk/LL and 2.98 kg milk/day for milk/CI relative to local breed. This result is lower than breed additive difference of 7.39 kg daily milk yield reported in a cross between Holstein Friesian * local breed Hirooka and Bhutyan (1995), and similar or higher with breed additive difference of 2.39 kg milk/day (milk/LL) and 1.47 kg/day milk (milk/CI) reported between Sahiwal * Brow Swiss crosses, (Mackinnon et al. 1996).

Table 3. Estimates of Breed additive, Heterosis and recombination losses on average daily milk yield (milk/LL) and milk yield per day of calving interval (milk/CI)

Parameter	Milk/LL (kg)		Milk/CI (kg)	
	Estimate	SE	Estimate	SE
Breed additive effect (GIF)	3.63**	0.521	2.98**	1.05
Individual heterosis effect (H^{I}_{FL})	1.08**	0.344	1.49*	0.64
Maternal heterosis effect (H^{M}_{FL})	-0.2785NS	0.49	0.88NS	0.68
Individual recombination (R^{I}_{FL})	-0.541NS	0.21	-2.75NS	2.09
Maternal recombination (R^{M}_{FL})	-1.11 NS	0.848	-	

Level of significance NS =P> 0.05, *= P<0.05, **= P< 0.01

The next most important genetic effect on average daily milk yield was individual heterosis. Heterosis with respect to Holstein Friesian and local breed genes had significant and positive effects on both traits. The estimate of 1.08 kg/day (proportionally 0.22) on milk/LL and 1.49 kg/day (proportionally 0.45) for milk/CI for full heterozygosity, is in agreement with heterosis effects of 1.04 kg/day on milk/LL and 1.22 kg/day of milk/CI reported on crossbreeding of *Bos Taurus X Bos idicus* (Mackinnon et al. 1996). Madsen & Vinther (1975), and Cunningham and Syrstad (1987) reports positive desirable heterosis for milk yield. However, Hirooka & Bhutyan (1995) reported a small and non-significant estimate of individual heterosis effects for average daily milk yield on crossbreeding between Bos Taurus and Bos indicus cattle in the tropics. These differences on estimates of heterosis for milk yield may be caused by differences of situations where the animals are reared.

Maternal heterosis effects were not significant for both traits (p>0.05). Ahlborn-Breier & Hohenbhoken (1991) reported similar non-significant effect of maternal heterosis on milk yield for crosses of Bos Taurus and Bos indicus breeds. However, Hirooka & Bhutyan (1995) obtained negative and significant estimate of maternal heterosis for average daily milk yield. The non-significance of maternal heterosis effect in this study may imply that recombination loss is not involved.

Estimate of individual and maternal recombination losses were negative but not significant (p>0.05). Taneja and Chawla (1978 b) found indication of large difference in maternal effect on milk yield in their study. However, when the present authors repeated their computations weighting various means according to numbers this indication disappeared. No other authors have been reported evidence of difference in maternal effects between *Bos Taurus* and *Bos indicus* with respect to milk yield.

The findings on additive genetic difference, heterosis and recombination effects were used to predict performance of various breed combinations, which are present or not present in the original data (Hirooka and Bhutyan 1995). Predicted average daily milk yields as a function of coefficients in Table 1 and crossbreeding parameters in Table 3 are presented in table 4. On the basis of these results, the 50% F1 and 15/16 crossbred cows were predicted to have the highest milk, while the 50% F1 cows had the highest observed least square means (table 3). When average daily milk yield and calving interval is combined into milk yield per day of calving intervals again both predicted and observed least square means were highest for 75% cross (F1).

Table 4. Predicted Average daily milk yield using genetic parameters from analysis (method 2)

Breed group	**Predicted milk yield/LL**	**Predicted milk yield/CI**
0% HF	3.11	1.99
25% HF	4.14	3.67
50% HF (F1)	6.00	4.97
50% HF (F2)	4.92	3.29
62.5% HF	5.67	4.89
75% HF	5.96	5.16
87.5% HF	6.03	4.89
93.75% HF	6.31	4.96
100% HF	6.74	4.97

HF= Holstein Friesian

Conclusion

The main aim of this study was to estimate the appropriate crossbreeding parameters and identify the optimum level of Holstein Friesian inheritance in crossbreeding program to genetically improve the herd. It was concluded that the milk production performance of (average daily milk) Arsi x Holstein Friesian crosses were heavily determined by heterosis (dominance effect). The observed and predicted results on both traits are in the same direction in favour of 50% (F1). The contribution of recombination effects in both individual and maternal traits was negligible.

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Characterizing lactation curve of indigenous and crossbred cows

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Abstract

Initial and peak milk yield, days to peak milk yield and persistency index (PI) of indigenous and crossbred cows were determined to characterized their lactation curve. The study was based on existing data in the Bako Agricultural Research Center and Debre Zeit Research Station. The overall mean initial and peak milk yield, days to peak and PI were 5.5 ± 0.07 kg, 8.2 ± 0.17 kg, 44.0 ± 1.17 days and 86.2 ± 0.70 %, respectively. Crossbred cows had significantly ($p < 0.001$) higher initial and peak milk yield and longer days to peak than the indigenous breeds. PI, however, was significantly ($p < 0.05$) higher in Simmental crosses compared to the other sire breeds considered. Among the crossbreeds, the Jersey crosses had significantly the highest initial (7.1 ± 0.24 kg) and peak milk yield (9.9± 0.21 kg) while the Simmental crosses had the longest days to peak (49.4 ± 4.32) and the highest PI (91.4 ± 1.83%). The Horro, as a sire breed, had significantly ($p < 0.001$) higher initial (3.3 ± 0.25 kg) and peak milk yield (5.5 ± 0.25 kg) than the Boran, while as a dam breed, the Boran had significantly (at least $p < 0.01$) higher peak milk yield (8.1 ± 0.16 kg) and longer days to peak (46.6 ± 2.22 days) than the Horro. The Debre Zeit herd had significantly ($p < 0.01$) higher initial (5.1 ± 0.25 kg) and peak milk yield (7.8 ± 0.25 kg), shorter days to peak (33.2 ± 4.39 days) and higher PI (89.2 ± 1.75 %) than the Bako herd. Parity significantly affected ($p < 0.001$) initial and peak milk yield only. Initial and peak milk yield showed curvilinear trend with parity, both increased till fourth parity and then started to decline. Cows that calved during Gana, Arfasa, Bona and Birra had the highest initial and peak milk yield, longest days to peak and highest PI, respectively. Significantly (at least $p < 0.05$) highest initial (5.9 ± 0.35 kg) and peak milk yield (8.5 ± 0.32 kg) were observed for cows that calved in 1981 while the longest days to peak milk yield was recorded for cows that calved in 1991 (53.7 ± 8.09 days).

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Covariance analysis of these traits on calving weight showed that initial milk yield (b = 0.014 ± 9.48), peak milk yield (b = 0.02 ± 10.1), days to peak (b = -0.082 ± 0.03) and PI (b = 0.015 ± 0.01) were linearly ($p < 0.001$) related to calving weight. Similarly, days to peak yield (b = -2.26 ± 0.05) and PI (b = -0.54 ± 0.22) were linearly ($p < 0.001$) related to initial milk yield. Correlation analyses of initial and peak milk yield, lactation yield, lactation length and PI with calving weight indicated positive correlation (range r = 0.148 to 0.826; $p < 0.001$), while the correlation of days to peak with calving weight was negative (r = -0.229; $p < 0.001$). Besides, initial and peak yield, lactation length and lactation yield were positively correlated between each other. From this study it can be concluded that crossbreeding improved the traits studied. Genetic and non-genetic factors affected the traits, and calving weight had an important role to play in improving the traits considered in this study. Further more, the correlation among the traits could be used as a basis for selection purposes.

Keywords/phrases: lactation curve, persistency, initial milk yield, peak milk yield, days to peak

Introduction

Low genetic merit for milk production of the indigenous cattle breeds has been identified as a constraint to dairy development in Ethiopia (Alberro and Haile-Mariam, 1982). As a result crossbreeding indigenous cattle with exotic sire breeds have been tried to upgrade the Horro and Boran local breeds. This made considerable improvement in growth and milk production in the F_1 generation (Sendros *et al.*, 1987; Chernet *et al.*, 2000). However, genetic improvement without the improvement in the feeding and management may not enable the improved genotypes to express their genetic potential.

Feeding a dairy cow is uniquely different from other aspects of livestock feeding because of variations in milk yield response to different feeding levels with the advance in lactation. Milk production on a daily basis is rather curvilinear in response to individual variations in initial and peak milk yield, days to peak yield and persistency of lactation which are important in characterizing a lactation curve (Koley *et al.*, 1981; Yadav and Sharma, 1985).

Under normal conditions the animal starts secreting milk immediately after parturition and the daily milk yield increase rapidly to a maximum between days 35 and 50 of lactation (Haresign, 1979). Dairy cows in the tropics have been reported to peak in milk yield between the third and sixth week after calving (El-Amin and Osman, 1971) while cattle under intensive production system in the temperate region peak at about five to six weeks of lactation followed by a continuous decline in production (Madalena *et al.*, 1979). Initial milk yield determines the starting point of the lactation curve and it is responsible for lowering or raising the lactation curve (Batra, 1986). Variations in peak accounted for 83% of variance in total yield, as compared to the variations accounted to persistency, which is 12%. This dominance of peak over persistency was also apparent in the mean effects of treatments applied over the whole lactation and influences the total lactation performance (Broster and Thomas, 1981).

Persistency is a measure of the shape of the lactation curve and it is a dimension less quantity (Wood, 1969; Cobby and Le Du, 1978) that can only be used for comparisons of lactation. Under favorable conditions, unbred cows produce each month 94% of their yield during the preceding month. Low persistency could be either inherited or due to under feeding or exhaustion of body reserves or other unknown mechanisms that compensate for the higher solicitation of the mammary gland at peak yield (Chilliard, 1992). Low persistency coefficients are characteristics of poor lactation milk yields and often of short lactation duration.

Several studies (Madalena et al., 1979; Koley et al., 1981; Yadav and Sharma, 1985; Ibeawuchi, 1988; Gashaw et al., 1994; Mureja, 1994) have tried to determine initial and peak milk yield, days to peak and persistency and reported different values due to differences in genotypes, management, parity, nutrition, age and calving season. Hence, determining these traits for a particular genotype under a specific management will enable to understand the characteristics of that lactation curve for that particular genotype and management and enable efficient allocation of inputs to maximize return. The objective of this study was, therefore, to characterize the lactation curve of indigenous and crossbred cows and see the effects of genetic and non genetic factors on these traits.

Materials and Methods

The study was conducted based on existing data from Bako Agricultural Research Center of Oromia Agricultural Research Institute and Debre Zeit Research Station of the International Livestock Research Institute (ILRI). Details of the two centers climatic condition, livestock management, breeding and health care are indicated in previous works (Gemechu, 1992;

Gebregziabher and Mulugeta, 1996). Lactation data of pure Horro and Boran cows and their F_1 crosses with Jersey, Friesian and Simmental exotic sire breeds obtained from Bako Agricultural Research center and lactation data of pure Boran and their crosses with Friesian exotic sire breed were used for the study. Lactation records of 1313 cows (787 records from Bako and 526 records from Debre Zeit) were used for the analysis. The traits considered were initial milk yield (first day milk yield after colostrum period), peak daily milk yield (the maximum daily yield in the ascending phase of lactation), days to peak milk yield (interval from calving to date of peak yield) and persistency (the extent to which peak yield is maintained).

Persistency was measured using persistency index calculated by the application of the method of ratios as described by El-Amin and Osman (1971) and Ibeawuchi (1988). For the calculation of persistency index, each lactation curve was divided into four equal parts of ten weeks each after excluding the first five weeks that represented the initial rising phase of the lactation curve. The total ten week yield of each of the four periods was then calculated and the following ratios established $R_1 = X_2/X_1$, $R_2 = X_3/X_2$ and $R_3 = X_4/X_3$; where X_1, X_2, X_3 and X_4 were total milk production during the four periods. The R_1, R_2 and R_3 were then used to calculate the following weighting factors (W_1, W_2 and W_3); $W_1 = R_1/(R_1 + R_2 + R_3)$; $W_2 = R_2/(R_1 + R_2 + R_3)$; $W_3 = R_3/(R_1 + R_2 + R_3)$. Persistency index (PI) was then calculated as $PI = (W_1 * X_2/X_1 + W_2 * X_3/X_2 + W_3 * X_4/X_3) * 100$. For cows with extended lactation yield of greater than 315 days, the yield beyond this period was not considered in the calculation of persistency index since such persistency measure does not allow inclusion of very long (greater than 305 days) and short lactations (less than 305 days).

All traits were analyzed using the General Linear Model (GLM) of the Statistical Analysis System (SAS, 1999). The GLM included fixed effects of sire and dam breed, parity, calving season and year and location. Besides, calving weight and initial milk yield were considered as covariate when days to peak, peak milk yield and persistency index were analyzed. Five sire breeds (Jersey for Boran x Jersey and Horro x Jersey; Simmental for Boran x Simmental and Horro x Simmental; Friesian for Boran x Friesian and Horro x Friesian; Boran for pure Boran and Horro for pure Horro); two dam breeds (Boran as dam breed for pure Boran and Boran crosses with Friesian, Jersey and Simmental; Horro as a dam breed for pure Horro and Horro crosses with Friesian, Jersey and Simmental), six parities (one to six with the sixth parity including parities six and above pooled together); four calving season categories based on the centers meteorological data: *Gana* (main rainy season) from June to August, *Birra* (spring) from September to November, *Bona* (dry season) from December to February and *Arfasa* (beginning of the rainy season) from March to May; nineteen calving years (1980 to 1998) and two locations (Bako and Debre Zeit) were considered as a fixed effects.

Results

Mean squares and least square means of initial and peak milk yield, days to peak milk yield and PI are presented in Tables 1, 2 & 3. The overall mean initial and peak milk yield, days to peak milk yield and PI were 5.5 ± 0.07 kg, 8.2 ± 0.17 kg, 44.0 ± 1.17 days and 86.2 ± 0.70 %, respectively. Crossbred cows had significantly ($p < 0.001$) higher initial and peak milk yield and longer days to peak than the indigenous breeds. Simmental crosses had significant ($p < 0.05$) the highest (91.4 ± 1.83%) PI while the Boran (81.0 ± 3.60%; Table 3) the lowest PI compared to the other sire breeds. Among the crossbreeds, the Jersey crosses had the highest initial (7.1 ± 0.24 kg) and peak (9.9 ± 0.21 kg) milk yield compared to the Friesian and Simmental crosses. The number of days to peak was not significantly different among the crosses. PI, however, was significantly ($p < 0.05$) highest for Simmental crosses (91.4 ± 1.83 %) than the Friesian (86.6 ± 0.96%) crosses (Table 3). As a sire breed, the Horro had significantly ($p < 0.001$) higher initial and peak milk yield than the Boran. While as a dam breed, Boran cows had significantly ($p < 0.001$) higher peak yield (8.1 vs. 7.0 kg) and longer days to peak (46.6 vs. 33.2 days) than Horro. Initial and peak milk yield showed a curvilinear trend with parity. Both initial and peak milk yield increased till fourth parity then started to decline. Cows in the first and sixth parities had significantly ($p < 0.001$) the lowest initial and peak milk yield compared to cows in the other parities. Debre Zeit herd had significantly (at least $p < 0.05$) higher initial milk yield (5.1 vs 4.5 kg), shorter days to peak (33.2 vs 46.6 days) and higher PI (89.2 vs 85.8 %) than the Bako herd (Tables 2 & 3).

Highest initial milk yield was observed for cows that calved during Gana (rainy season), while peak yield and days to peak milk yield were highest for cows that calved during Arfasa (short rainy season) and Bona (dry season). Highest PI was observed for cows that calved during Birra (post-rainy season) (Table 3). Significantly (at least $p < 0.05$) highest initial (5.9 ± 0.35 kg) and peak milk yield (8.5 ± 0.32 kg) were observed for cows that calved in

1981 while the longest days to peak milk yield was recorded for cows that calved in 1991 (53.7 ± 8.09 days; Table 2).

Covariance analysis of initial and peak milk yield, days to peak and PI on calving weight showed that all traits were linearly ($p < 0.001$) related to cow weight at calving. Similarly, days to peak yield and PI were linearly ($p < 0.001$) related to initial milk yield (Table 2 & 3). Correlation analysis of initial and peak milk yield, days to peak yield, lactation yield, lactation length and PI with calving weight indicated significantly positive correlation (range r = 0.148 to 0.826; $p < 0.001$), while the correlation of days to peak with calving weight was negative (r = -0.229). Besides, initial and peak yield, lactation length and lactation yield were positively correlated between each other (Table 4).

Discussion

In characterizing lactation curve the traits initial and peak milk production, days to peak and persistency index indicate where the curve starts and peaks, number of days required to peak and the shape of the curve after peak production is reached. In this study, the least square mean values of initial milk yield, peak milk yield, days to peak and PI were 5.5 ± 0.07 kg, 8.2 ± 0.17 kg, 44.0 ± 1.17 days and 86.2 ± 0.70 %, respectively. These values are comparable to the reported values in the literature (Haresign, 1979; Ibeawuchi, 1988; Singh *et al.*, 1989, Kumar *et al.*, 1999). However, it is lower than peak yield reported by Koley *et al.* (1981), Rao and Sundarsen (1982), Hahn (1988) and Gashaw (1994). The variation in the values of the traits among the different studies could be due to differences in genotypes used, the non-genetic factors that affect the trait and variations in the objectives of the different farms (Gill *et al.*, 1971; Madsen, 1975; Koley *et al.*, 1981; Gashaw, 1994; Mureja, 1994). The higher values reported by Mureja (1994) for instance was based on data from commercial dairy farms where the farms objective is high milk production for sale and is based on higher grade Friesian crossbred cows, while this study is based on data from experimental stations where the management is not highly intensified to exploit the genetic potential of the animals for milk production. This might have resulted in lower values of these traits in this study compared to what Mureja (1994) reported.

Significant breed differences, in initial milk yield, peak milk yield, days to peak and PI were observed in this and earlier studies (Rao and Sundaresan, 1982; Kiwuwa *et al.*, 1985; Zaman, 1988; Singh *et al.*, 1989; Gashaw, 1994).

This could be associated with the difference in genetic make up of breeds for milk production. Crossbred and higher-grade exotic breeds yielded higher milk yield compared to the indigenous breeds (Sendros *et al*., 1987; Chernet *et al*., 2000; Gebregziabher *et al*., 2003). Lactation milk yield is highly correlated with initial and peak milk yield, days to peak milk yield and persistency (Koley *et al*., 1981; Yadav and Sharma, 1985; Roy and Katpatal, 1988; Zaman *et al*., 1998). Similar correlation has been observed in this study (Table 4). High yielding cows had significantly higher values of initial and peak milk yield, longer days to peak and higher PI compared to cows with lower lactation yields. Thus, crossbred cows, which yielded higher lactation milk, gave higher values of initial and peak milk yield, longer days to peak and higher persistency compared to the indigenous breeds. This could be due to additive gene effect when *Bos indicus* (zebu) is crossed with the *Bos taurus* breeds.

Initial and peak milk yields showed a curvilinear trend with parity order having the lowest values for cows in the first and sixth parities (Table 1&2). An increase in initial milk yield up to the fourth lactation was observed. This is in agreement with the work of Yadav and Sharma (1985). Milk secretory tissue in primiparous animals takes longer to reach its peak activity than in pluriparous animals (Rao and Sundaresan, 1979), hence primiparous animals show lower initial milk yield compared to pluriparuou cows. As the heifers continue to grow, their mammary development do not reach its full maturity, more sectetory cells continue to proliferate, this might have resulted in lower initial milk yield of heifers compared to relatively mature cows. Mature cows on the other hand have matured mammary system and hence, yield higher at start of the lactation. As the lactation advances, a decrease in the number of the secretory cells results in a decrease in milk yield. The effect of parity on days to peak and PI obtained in this study was not significant which is contrary to other reports (El-Amen and Osman, 1971; Rao and Sundarsan (1979). The lactation curve for cows in the first parity and those which are low producers are flatter than lactation curves of cows in other parities and that of high producers (Yadav and Sharma, 1985) indicating lower peak milk yield and higher persistency for cows in the first parity and for those that are low producers. Similar, parity effect on peak milk yield was reported from previous works (Keown *et al.,* 1986; Kabuga and Agyemang, 1984; Bhutia *et al*., 1989) but others (Bhutia *et al.,* 1988;

Singh and Gopal, 1982) reported non significant parity effect on peak milk yield.

Table 1. Mean square, coefficient of variation (CV%) and R^2 from least square analysis of variance of initial milk yield, peak milk yield, days to peak milk yield and PI

Source	**Df**	**Initial milk yield**	**Peak milk yield**	**Days to peak**	**PI**
Sire breed	4	500.2 ***	797.9 ***	7632.5 ***	48.6 *
Dam breed	1	1.0 NS	148.5 ***	19403.5 ***	3.6 NS
Calving year	18	33.1 ***	22.2 ***	1909.8 *	-
Calving season	3	39.9 ***	53.6 ***	28166.5 ***	1226.8 ***
Parity	5	47.1 ***	40.9 ***	395.2 NS	314.7 NS
Location	1	54.7 **	9.9 NS	7708.4 *	1467.4 **
Regression					
Initial milk yield	1	-	-	26661.6 ***	908.7 *
Calving weight	1	510.1***	603.5 ***	10785.7 **	718.6 *
Error df		1279	1273	938	478
Error mean square		5.7	5.4	1323.3	145.8
CV (%)		43.3	28.3	82.7	13.9
R^2 (%)		53.5	63.3	19.3	10.9

Significance level: *** = p < 0.001; ** = p < 0.01; * = p < 0.05 NS =not significant

Significant differences were observed between locations and among calving seasons and years in initial milk yield, peak milk yield and days to peak milk yield. Difference between locations could be related to differences in herd management. Besides, variations in the availability of feed both in quality and quantity also contributes to calving season and year variations. Similar results were reported for peak milk yield, days to peak and PI (Rao and Sundersan, 1981; 1982; Mureja, 1994; Zaman *et al.*, 1998). Raheja (1982) reported that cows that calved during cold comfort season took comparatively shorter time to attain peak in all genetic groups they considered that could be attributed to favorable climatic conditions and availability of fodder of good quality during this season, which is in agreement to the shortest days to peak and higher initial milk yield obtained for cows that calved during Gana (wet season) in this study (Tables 2&3).

Cow weight at calving was linearly and directly related to initial and peak milk yields and inversely related to days to peak and PI (Tables 1, 2 and 3) probably associated with the age of the cows and availability of body reserve for high milk production. More mature cows which are relatively heavier at calving showed higher initial and peak milk yield and shorter days to peak and lower PI compared to lighter cows at calving. After calving the metabolic activity of secretory cells is dependent on the availability of nutrients in the blood that are used in milk synthesis (Chilliard, 1992). The closer relationship which exist between milk yield and energy balance is highly correlated during early lactation. Individual cows meet their energy demands through combinations of feed intake and mobilization of body reserve (Butler *et al.*, 1981). Thus, heavier cows and cows with greater body reserves at calving and the ability to use these reserves during the postpartum period can partly overcome the negative energy balance during earlier lactation, which probably resulted in higher initial and peak milk yield (Coppock *et al.*, 1974; Butler *et al.*, 1981). Moreover, the ability to rapidly mobilize body reserve for milk production during early lactation might enabled the cows to reach their peak yield within shorter period of time and lower the persistency of lactation. Initial milk yield was inversely related to days to peak and PI (Table 4) indicating that an increase in initial milk yield results in shorter days to peak and lower PI.

Correlation (Table 4) of peak milk yield, lactation length, initial milk yield and lactation yield with calving weight are positive (range $r = 0.312$ to 0.836; $p < 0.001$). The positive correlation reported (Singh and Gopal, 1982; Koley *et al.,* 1981) between peak milk yield and lactation yield and negative correlation of initial milk yield with days to peak (Bhutia and Pandy, 1988) is consistent with the present work (Table 4).

Table 2. Least square means (± SE) initial and peak milk yield (kg), and days to peak yield

Source	**N**	**Initial yield**	**N**	**Peak yield**	**N**	**Days to peak**
Overall mean	1313	5.5 ± 0.07	999	8.2 ± 0.17	973	44.0 ± 1.17
Sire breed		***		***		***
Friesian crosses	651	6.5 ± 0.13 [b]	339	8.9 ± 0.13 [b]	331	45.3 ± 2.65 [a]
Jersey crosses	183	7.1 ± 0.22 [a]	179	9.9 ± 0.21 [a]	176	47.3 ± 3.65 [a]
Simmental crosses	124	6.1 ± 0.25 [b]	118	9.7 ± 0.25 [a]	116	49.4 ± 4.32 [a]
Horro	255	3.3 ± 0.25 [d]	253	5.5 ± 0.25 [c]	250	30.7 ± 4.52 [b]
Boran	100	2.5 ± 0.25 [c]	110	3.9 ± 0.26 [d]	100	26.8 ± 4.16 [b]
Dam breed		NS		***		**
Boran	794	5.1 ± 0.12	489	8.1 ± 0.16 [a]	471	46.6 ± 2.22 [a]
Horro	519	5.1 ± 0.19	510	7.0 ± 0.20 [b]	502	33.2 ± 3.03 [b]

Table 2. Continued.

Source	**N**	**Initial yield**	**N**	**Peak yield**	**N**	**Days to peak**
Location		**		NS		*
Bako	787	4.5 ± 0.14^{a}	780	7.4 ± 0.12^{a}	762	46.6 ± 2.02^{a}
Debre Zeit	526	5.1 ± 0.25^{b}	219	7.8 ± 0.25^{b}	211	33.2 ± 4.39^{b}
Season of calving		***		***		***
Gana (June-August)	283	5.5 ± 0.17^{a}	209	7.7 ± 0.17^{ab}	205	30.0 ± 3.05^{c}
Birra (Sep. – November)	293	4.7 ± 0.17^{b}	207	7.0 ± 0.17^{c}	204	37.2 ± 3.11^{b}
Bona (Dec. –February)	303	4.9 ± 0.17^{b}	253	7.5 ± 0.16^{b}	243	56.3 ± 2.85^{a}
Arfasa (March-May)	434	5.3 ± 0.15^{a}	330	8.0 ± 0.15^{a}	321	36.1 ± 2.64^{bc}
Parity		***		***		NS
1	262	4.2 ± 0.19^{c}	188	6.8 ± 0.18^{c}	184	38.3 ± 3.24
2	229	5.2 ± 0.19^{ab}	162	7.9 ± 0.19^{a}	155	41.1 ± 3.48
3	256	5.5 ± 0.18^{a}	200	8.0 ± 0.17^{a}	196	41.9 ± 3.11
4	227	5.5 ± 0.19^{a}	176	8.0 ± 0.18^{a}	170	41.1 ± 3.38
5	170	5.4 ± 0.21^{a}	141	7.7 ± 0.20^{ab}	139	38.8 ± 3.64
6	169	4.8 ± 0.22^{b}	132	7.2 ± 0.21^{bc}	129	38.2 ± 3.93
Calving year		***		***		*
1980	71	5.8 ± 0.37^{ab}	64	8.4 ± 0.36^{a}	63	42.5 ± 5.91^{abcde}
1981	79	5.9 ± 0.35^{a}	78	8.5 ± 0.32^{a}	76	44.1 ± 5.31^{abcde}
1982	100	5.2 ± 0.33^{bcd}	98	7.9 ± 0.31^{abc}	96	42.6 ± 4.96^{abcde}
1983	63	3.4 ± 0.37^{fg}	64	7.2 ± 0.35^{def}	62	50.2 ± 5.59^{ab}
1984	36	4.1 ± 0.44^{defg}	39	7.1 ± 0.41^{def}	35	35.9 ± 6.81^{abcde}
1985	43	4.3 ± 0.42^{def}	42	7.5 ± 0.39^{bcdef}	42	35.1 ± 6.31^{cde}
1986	64	4.8 ± 0.36^{cde}	63	7.3 ± 0.33^{cdef}	63	31.8 ± 5.37^{e}
1987	47	4.9 ± 0.39^{bcd}	49	7.8 ± 0.36^{abcde}	46	47.6 ± 5.89^{abcd}
1988	44	5.9 ± 0.40^{ab}	47	7.8 ± 0.37^{abcde}	44	37.1 ± 6.05^{abcde}
1989	19	5.7 ± 0.56^{abcd}	19	7.7 ± 0.55^{abcdef}	19	31.2 ± 8.72^{e}
1990	112	4.9 ± 0.25^{de}	109	8.0 ± 0.24^{abc}	68	35.8 ± 4.66^{bcde}
1991	48	3.6 ± 0.36^{g}	49	7.1 ± 0.35^{def}	22	53.7 ± 8.09^{a}
1992	66	4.5 ± 0.32^{def}	64	7.3 ± 0.31^{def}	32	42.7 ± 6.62^{abcde}
1993	77	4.4 ± 0.29^{efg}	81	7.1 ± 0.28^{ef}	34	30.6 ± 6.41^{e}
1994	93	3.9 ± 0.27^{fg}	97	6.5 ± 0.26^{f}	51	33.5 ± 5.44^{de}
1995	108	5.2 ± 0.25^{bcd}	109	7.9 ± 0.24^{abcd}	66	36.3 ± 4.75^{abcde}
1996	70	5.1 ± 0.31^{cde}	68	7.5 ± 0.30^{cdef}	42	39.8 ± 5.93^{abcde}
1997	83	5.4 ± 0.29^{abcd}	83	8.4 ± 0.28^{ab}	57	37.1 ± 5.16^{abcde}
1998	90	4.5 ± 0.29^{def}	84	6.6 ± 0.28^{f}	55	49.9 ± 5.27^{abc}

Table 2. Continued.

Source	**N**	**Initial yield**	**N**	**Peak yield**	**N**	**Days to peak**
Covariate						
Calving weight		0.014 ± 9.48***		0.02 ± 10.1***		-0.082 ± 0.03***
Initial milk yield						-2.26 ± 0.05***

Means in a column in a group with different superscript vary significantly (*** = p < 0.001, ** = p < 0.01,
* = p < 0.05, NS = not significant

Table 3. Least square mean (± SE) PI

Source	**N**	**PI (%)**
Overall mean	311	86.2 ± 0.70
Sire breed		*
Friesian crosses	142	86.6 ± 0.96 [bc]
Jersey crosses	72	89.1 ± 1.76 [ab]
Simmental crosses	73	91.4 ± 1.83 [a]
Horro	11	83.6 ± 4.03 [bc]
Boran	13	81.0 ± 3.60 [c]
Dam breed		NS
Boran	388	85.8 ± 1.29
Horro	102	86.9 ± 1.71
Location		**
Bako	236	83.5 ± 1.27 [a]
Debre Zeit	75	89.2 ± 1.75 [b]
Season of calving		***
Gana (June – August)	67	87.7 ± 1.59 [a]
Birra (Sept.– Nov.)	56	89.6 ± 1.67 [a]
Bona (Dec. – February)	86	85.4 ± 1.62 [a]
Arfasa (March – May)	102	82.7 ± 1.51 [b]
Parity		NS
1	116	88.2 ± 1.77
2	96	86.9 ± 1.70
3	106	85.4 ± 1.61
4	93	86.2 ± 1.69
5	49	86.8 ± 2.03
6	35	84.6 ± 2.32
Covariates		
Calving weight		-0.015 ± 0.01***
Initial milk yield		-0.54 ± 0.22 ***

Means in a column in a group with different superscript vary significantly (*** = p < 0.001, ** = p < 0.01, * = p < 0.05, NS = not significant

Table 4. Correlation analysis of initial (INY), peak milk yield (PKY), lactation length (LAL), lactation yield (LYLD), days to peak (DPKY) , persistency index (PI) and calving weight (CWT)

	INY	PKY	LAL	LYLD	DPKY	PI
CWT	0.533 ***	0.568***	0.148***	0.447***	-0.229 ***	-0.059 ns
INY		0.836***	0.312***	0.701***	-0.299 ***	-0.116 **
PKY			0.392***	0.826***	-0.135 ***	-0.154 ***
LAL				0.706***	0.041 NS	0.215 ***
LYLD					-0.001 NS	0.099 *

Significance level *** = p < 0.001, ** = p < 0.01, * = p < 0.05 and NS = non significant

Conclusion

The following conclusions could be drawn from this work

- The overall mean initial and peak milk yield were lower and days to peak shorter and PI comparable to other studies. Crossbred cows had higher initial and peak milk yield, longer days to peak than indigenous breeds. This indicates that those traits are improved through crossbreeding.
- Apart from the breed difference observed in this study, the traits were affected by non-genetic factors such as calving weight, calving season and year, location and parity of the cow.
- All traits were related to cow weight at calving and heavier weights resulted in higher initial and peak milk yield and shorter days to peak and lower persistency.
- The PI used to measure persistency of lactation takes 305 days lactation yield except the ascending phase. Since most of the indigenous cows had shorter lactation period, they were not included in the calculation of PI. Hence, such measure of persistency might not be appropriate to use for cows with short lactation period. Therefore, appropriate persistency measures, for cows with short lactations, need to be sought and evaluated.

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Modeling lactation curve and comparison of model's fitness to different lactation data of indigenous and crossbred cows

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Abstract

Five lactation curve models were compared for their fitness to milk data of indigenous and crossbred cows using data from Bako Agricultural Research Center and Debre Zeit Research Station. The fit of the models was compared using the model R^2 value. The overall mean R^2 value was 81.5 ± 0.12% and was significantly ($p < 0.001$) affected by model type, data type, sire breed, parity, calving season and year, location and the interactions of model type with these fixed effects. The mean R^2 values for the Incomplete Gamma with two parameters (IG ($b = 1$)), Inverse polynomial (IP), Exponential, Incomplete Gamma (IG ($b \neq 1$)) and Parabolic exponential models were 90.1 ± 0.26, 90.2 ± 0.26, 67.2 ± 0.28, 74.7 ± 0.26 and 77.8 ± 0.26 percent, respectively. Higher values of R^2 were obtained for the Debre Zeit (80.5 %) herd than Bako. The sire breeds Friesian (81.6%) crosses had significantly the highest R^2 value compared to the other sire breeds. Cows that calved during Arfasa (83.4%) had a higher fit than those in other calving seasons. Among the data types considered, highest R^2 was observed for monthly mean (85.6%) and monthly total (85.6 %) milk data types. Besides, cows in the sixth parity (81.3 %) and those that calved in 1993 (84.5 %) had the highest R^2 value. The highest R^2 was obtained for IP fitted to monthly mean (95.4 %) and monthly total (95.4 %) milk data followed by the IG ($b = 1$) fitted to monthly mean (93.2 %) and monthly total (93.2 %) milk data types. The IP followed by IG ($b = 1$) fitted to milk data of the crossbreds had the highest R^2. The reverse is true for the indigenous breeds. Among the model type x parity, model type x season and model type x location interaction groups, the IP followed by IG ($b = 1$) had the highest R^2 for all parities, calving seasons and locations. From this study it can be concluded

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that both the IP and IG (b=1) had the best fit and could be used to describe the lactation curves of both zebu and crossbred cows under study.

Key words: lactation curve, model, fitness, crossbred

Introduction

Lactation curve, the graphical representation of milk yields over time (Papajcsik and Bodero, 1988; Sherchand *et al.*, 1995), is determined by the biological efficiency of the cow and is used for selection and feeding management. When a functional form is used to describe a lactation curve, the predicted milk yield at any given stage of lactation can be used as a basis for decisions to cull or retain for breeding (Wood, 1969; Madalena *et al.*, 1979; Papajcsik and Bodero, 1988; Sherchand *et al.*, 1995). Mathematical models of lactation curve are required to abstract the true situation of milk secretion during the entire lactation (Singh and Bhat, 1978). Several models have been developed and tested to describe such a lactation pattern of milk production (Papajcsik and Bodero, 1988; Sherchand *et al.*, 1995; Olori *et al.*, 1999). Models vary with respect to the number of parameters in the equation, the method of estimating model parameters, method of fitting the equations to the lactation data, simplicity to fit to lactation data and interpret and relate these parameters to the actual situations. Based on these facts five lactation curve models (Incomplete Gamma with three and two parameters, Inverse Polynomial, Exponential and Parabolic exponential) have been selected for this purpose.

Incomplete Gamma function (Wood, 1967) is the most commonly used functional form for the lactation curve of the dairy cow. The model predicts a peak yield of "$a(b/c)^b \exp(-b)$" which occurs "b/c" days after calving and persistency of "$C^{-(b+1)}$". Exponential Model (Brody *et al.*, 1923) fits to the declining phase of the lactation curve. The drawback reported for this model was that it did not generate a rise in the curve because of exclusion of an inclining function (Sherchand *et al.*, 1995). A parabolic exponential model (Sikka, 1950) is used to represent a lactation curve with the day of peak yield "(b/2c)" corresponding to the mean of the distribution. The model gave good fit to first lactation data (Singh and Bhat, 1978). But it did not fit at all before the peak was attained, because the function is symmetric around peak yield (Sherchand *et al.*, 1995). The inverse polynomial (Nelder, 1966) has been used to model lactation curves (Yadav *et al.*, 1977; Singh and Bhat, 1978; Kumar and Bhat, 1979; Batra, 1986) and reported the model to give a good fit for lactations, which start at a low level and peak earlier than average (Kumar and Bhat, 1979). In the Incomplete Gamma with two parameters (Papajcsik and Bodero, 1988), the values of the Wood's parameter (Wood, 1967) "b", was considered as one. The fit of these models is different due to several reasons. To this effect different authors have tested and recommended different models for different herds. The objective in this study is therefore, to compare the fit of these five models to the lactation data of indigenous and crossbred cows and select a model, which best describes the lactation curves of both crossbred and indigenous breeds.

Materials and Methods

The study was conducted based on existing data from Bako Agricultural Research Center of Oromia Agricultural Research Institute and Debre Zeit Research Station of the International Livestock Research Institute (ILRI). Details of the two centers climatic condition, livestock management, breeding and health care are reported in previous works (Gemechu, 1992; Gebregziabher and Mulugeta, 1996). Lactation data of pure Horro and Boran and their F_1 crosses with Jersey, Friesian and Simmental exotic sire breeds were used for the study. The five models fitted to milk yield data of indigenous and crossbred cows and their logarithmic transformed equivalents are listed blow.

Model name and reference	**Original Model**	**Transformed model**
1. Incomplete gamma function (Wood, 1967)	$Y_N = AN^b \exp(-cN)$	$Ln(Y_N) = Ln(A) + bLn(N) - cN \quad b \neq 1$
2. Incomplete gamma function with two parameters (Papajicsik and Bodero, 1988)	$Y_N = AN^b \exp(-cN) \quad b = 1$	$Ln(Y_N/N) = Ln(A) - cN$
3. Exponential model (Brody et al., 1923)	$Y_N = A\exp(-cN)$;	$Ln(Y_N) = Ln(A) - cN$
4. Parabolic exponential model (Sikka, 1950)	$Y_N = A\exp(bN - cN^2)$	$Ln(Y_N) = Ln(A) + bN - cN^2$
5. Inverse polynomial model (Nelder, 1966)	$Y_N = N(A_0 + A_1N + A_2N^2)^{-1}$	Not transformed

In the models, "Ln" represents the logarithm to base "e", "Y_N" represents milk yield (total or mean) recorded at N interval (daily, weekly, fortnightly or monthly) from calving depending on the type of data used for a particular interval of recording. "Ln (A)" or "a", "b", "c", "A_0", "A_1" and "A_2" are to be estimated from the regression analysis. In the models the parameter "a" is defined as "the scale of production" (Wood, 1972) or "initial milk production" (Madalena *et al.*, 1979) while "c" represents the rate of change in the declining phase of lactation curve (Yadav *et al.*, 1977). In the IP function the parameters measure the rate of increase to peak production ("A_0"), the average slope of the lactation curve ("A_1") and the rate of decline after the peak ("A_2"). All models, except the IP, were first transformed to their linear form using logarithmic transformation. The models were fitted to each lactation data of each cow using the Regression Procedure of the Statistical Analysis System (SAS, 1999). The model R^2 obtained as an output of the regression analysis was subjected to analysis of variance using a General Linear Model to see the effects of both genetic and non-genetic factors following the method of Olori *et al.* (1999). The general linear model used for the analysis of this data included fixed effects of sire breed, model type, data type, calving season, calving year, parity and location and the interactions of model type with these fixed effects only. Detailed descriptions of these fixed effects are presented in Gebregziabher *et al.* (2003). Besides, seven milk yield data types (daily, weekly mean and total, fortnightly mean and total, monthly mean and total) and five model types were considered as fixed effects.

Results

The overall mean R^2 value was 81.5 ± 0.21%. The effects of sire breed, dam breed, parity, calving season and year, data type, model type and the interaction of model type with these fixed effects were significant ($p < 0.001$; Table 1). Significantly ($p < 0.001$) highest value of R^2 was obtained for IG (b = 1) (90.1 ± 0.26) and IP (90.2 ± 0.26) models and the poorest fit was observed on the exponential model (Table 2). Similarly the highest R^2 values was observed for Debre Zeit (80.5 ± 0.26 %) than Bako (79.3 ± 0.14) herd; for Friesian (81.6 ± 0.13%) and Jersey (81.1 ± 0.22 %) crosses; for cows that calved during Arfasa (83.5 ± 0.17%); for monthly mean (85.6 ± 0.22%) and monthly total (85.6 ± 0.22%) milk data types; for cows in the sixth parity (81.3 ± 0.23%); and for cows that calved in 1993 (84.5 ± 0.37%) compared to their contemporaries (Table 2).

Among the model x data type interaction groups, except when fitted to daily data, the IP followed by the IG (b = 1) was found to have the best fit to the data. The highest R^2 was obtained for IP followed by the IG (b = 1) fitted to monthly mean and monthly total milk yield (Table 2). Among the model type by sire breed interaction groups the IP followed by IG (b = 1) fitted to milk data of the crossbred cows had the highest R^2; while the reverse is true for the indigenous breeds (Table 2). Among the model type x parity, model type x calving season and model type x location interaction groups, the IP followed by IG (b = 1) had the highest R^2 for all parities, seasons and locations (Table 2). Besides, all models had a better fit to lactation data of cows that calved during Arfasa (short rainy season) compared to the other calving season x model interaction groups. Both IP and IG (b = 1) were superior to the other models and had the best fit for lactation data of cows in the later (5 - 6) than earlier (1 - 4) parities (Table 2).

Table 1. Mean square, coefficient of variation (CV%) and R^2 from least square analysis of variance of R^2

Sources	**Df**	**Mean square**
Model	4	36.4 ***
Sire breed	4	1.5 ***
Calving season	3	10.2 ***
Calving year	18	2.8 ***
Data type	6	14.6 ***
Parity	5	1.2 ***
Location	1	0.3 ***
Data type x model	24	0.31 ***
Sire x model	16	0.33 ***
Parity x model	20	0.38 ***
Season x model	12	1.14 ***
Location x model	4	0.39 ***
Error	43927	0.025
CV (%)		19.4
R^2 (%)		31.9

Significance level *** p < 0.001

Discussion

The fitness of the models to the lactation data of indigenous and crossbred cows as measured by the overall mean R^2 value was 81.5 % (Table 2) which is lower than the highest value of 99% reported by Singh and Bhat (1978) but comparable to the 82% reported by Wood (1968). Variations in R^2 values are expected because of differences in locations, genotypes, parities, calving seasons and calving years, which directly or indirectly affect the fitness of the models (Cobby and Le Du, 1978; Keown *et al.*, 1986).

Several models have been tested for fitness to different data (Brody *et al.*, 1923; Sikka, 1950; Wood, 1967; Cobby and Le Du, 1978; Keown *et al.*, 1986) and vary in ease of application, parameters involved, method of application and estimation of model parameters (Cobby and Le Du, 1978). Thus, the variance explained by these models is different. The significantly higher variation in R^2 value among models (Table 2) obtained in this study could be attributed to these reasons.

The superiority of the IG ($b = 1$) over the exponential and IP (Papajicsik and Bodero, 1988) and the IP over the IG ($b \neq 1$), the parabolic exponential and exponential functions (Singh and Bhat, 1978; Bhat *et al.*, 1981; Batra, 1986; Gahlot *et al.*, 1989) were already reported elsewhere. However, Singh *et al.* (1997) reported the superiority of IG ($b \neq 1$) followed by parabolic exponential, IP and exponential function when fitted to the monthly milk records of first lactation cows. The reason for this difference could be due to differences in the type of data used. Gahlot *et al.* (1989), however, reported lower estimate of R^2 value for exponential function and higher estimates of R^2 value for IG ($b \neq 1$) as compared to parabolic exponential and exponential functions. Similar results have been obtained in this study for all data types (Table 2). Besides, they reported that the IG ($b \neq 1$) explained maximum variation for each genetic group, indicating better fit of the curve over parabolic and exponential function, while the exponential function had poor fit to the data. In a study by Sikka (1950) the addition of parabolic term to exponential function increased the proportion of variation explained by the parabolic exponential model, while Yadav and Sharma (1985) reported that the percentage variation accounted for by the exponential parabolic function was not greater than and in most cases they were lesser than that accounted for by an exponential function, which indicated that the addition of the parabolic term to exponential function did not improve the fit of the curve to Hariana crossbred cows. In this study addition of the parabolic term improved the fitness of the exponential function for all data types, which is in agreement to Sikka (1950). Comparison of the IG ($b = 1$) and IG ($b \neq 1$) indicated that the IG($b = 1$) was found to fit better than IG($b \neq 1$). The parameter "b" which represents the rate of increase to peak milk yield, when it equals one indicates that there is a steep slop to peak or shorter ascending phase of the lactation. Therefore, lactation data of the studied herds behaved that it started at higher level and then declines thereafter. This could be associated with the level of feeding during early periods of lactation.

The type of data to which the models were fitted also affected the R^2 values. Several works reported on the fit of the models to daily (Madalena *et al.*, 1979; Abubakar and Buvanendran, 1981), weekly (Rao and Sundaresan, 1982; Yadav and Sharma, 1985; Batra, 1986) and monthly (Singh *et al.*, 1997) milk data based on the mean or the total milk yield. Similarly, this study confirmed the variation in the fit of the models to different data types. Highest fit of the models was observed for monthly followed by fortnightly and weekly data and the lowest for daily milk yield data. This could be associated with the high individual variability (high standard deviation) in the daily data compared to the monthly, fortnightly and weekly mean milk data, which has relatively lower individual variability or standard error.

The variation among calving seasons in fitness is related to variation in the availability of feed both in quantity and quality. The flush of pasture growth during the wet season (Gana) gives a stimulus to milk production since cows that calved during Arfasa (short rainy season) had their peak milk yield that coincided with the wet season. Those animals have only one hump in their lactation curve that is due to one peak yield. The model, therefore, gave a better fit to those lactations than those commencing during the other periods where the wet season may stimulate increase in milk yield resulting in a second hump in addition to the peak in the lactation curve which is in agreement to the report of Abubakar and Buvanendran (1981).

The fact that the lactation curves of crossbred cows had better fit compared to those of indigenous breeds could be related to the fact that the indigenous breeds are not selected for milk production. These lactation curve models are developed for specialized dairy breeds. Besides, the sire breed difference could be related to the lactation yield and lactation length of the cows where the crossbreds yielded higher and milked longer than the indigenous breeds (Sendros *et al*., 1987). Similar breed differences were also reported from Indian studies (Singh and Bhat, 1978; Yadav and Sharma, 1985).

The fitness of the five models was different among the data types (Table 2). Similarly, Wood (1969) reported that the exponential function had better fit accounting for 95.4% of the variation in monthly milk yield as against 84.4% for the IP function. Olori *et al.* (1999) also reported the dependence of the goodness of fit on whether the objective is to predict the cumulative yield or individual daily yields, and on whether the observation units are groups of animals or individual animals. Rowlands *et al.* (1982), in their work to determine the goodness of fit of models to weekly records, found a wide range in variation which they attributed to the effects of several environmental and genetic factors. Collins-Lusweti (1989, 1991) also reported lower goodness of fit (R^2) values for the monthly than weekly total milk yields, with the R^2 values being 74.8 and 79.2 percent, respectively. This is contrary to the higher R^2 values obtained for data based on monthly than weekly total milk data in the present study (Table 2).

Lactation curve models and estimation of their parameters is geared to wards practical use in dairy farm management and for milk yield estimation. Different data types have been compared in this study. The fitness of the models to monthly data is better than fortnightly and weekly data. However, for practical intervention of any management practice the interval of measurement has to be short so that any thing that might happen within that interval could be addressed immediately. The formulation of feeding ration is based on the milk output in specific stages of lactation thus, information on the milk output of the cows in a weekly or biweekly interval is required.

Conclusion

From this study the following conclusions could be drawn

- Five models were fitted to lactation data of zebu and crossbred cows. The fitness of the models was different for different data types, breeds, locations, parities and calving seasons, calving year, model type and the interaction of model type with the other fixed effects.
- Among the models compared, the IP and IG (b = 1) were the best models to describe the lactation curve of both indigenous and crossbred cows. However, the fitness was better for crossbred than indigenous cows.
- The fitness of the models was best for monthly milk data types. However, using monthly records do not ease practical application of the models to any management interventions. Thus, it is recommended to use the selected models on weekly total milk data.

Table 2. Least square mean (± SE) R^2 values (%)

Source of variation	**N**	**Mean ± S.E.**
Overall mean	44045	81.5 ± 0.21
Model type		***
Incomplete gamma (IG) (b = 1)	9005	90.1 ± 0.26 [a]
Incomplete gamma (IG (b ≠ 1))	8920	74.7 ± 0.26 [c]
Exp (EXP)	8215	67.2 ± 0.28 [d]
Pexp (PEXP)	8902	77.8 ± 0.26 [b]
IP (IP)	9003	90.2 ± 0.26 [a]
Sire breed		***
Friesian crossbreds	21215	81.6 ± 0.13 [a]
Jersey crossbreds	8084	81.1 ± 0.22 [b]
Simmental crossbreds	4059	80.8 ± 0.26 [bc]
Boran	2321	76.1 ± 0.34 [d]
Horro	7566	80.2 ± 0.28 [c]
Calving season		***
Gana (June - August)	9174	81.2 ± 0.20 [b]
Birra (September-November)	9860	76.5 ± 0.19 [d]
Bona (December – February)	10440	78.7 ± 0.18 [c]
Arfasa (March – May)	14571	83.5 ± 0.17 [a]
Data type		***
Daily	6242	72.1 ± 0.22 [d]
Weekly mean	6284	77.5 ± 0.22 [c]
Weekly total	6202	77.3 ± 0.22 [c]
Fortnight mean	6306	80.9 ± 0.22 [b]
Fortnight total	6304	80.7 ± 0.22 [b]
Monthly mean	6314	85.6 ± 0.22 [a]
Monthly total	6313	85.6 ± 0.22 [a]
Parity		***
1	7514	77.2 ± 0.21 [c]
2	7565	80.1 ± 0.22 [b]
3	8883	80.3 ± 0.20 [b]
4	7797	80.1 ± 0.21 [b]
5	5845	80.6 ± 0.23 [b]
6	6441	81.3 ± 0.23 [a]

Table 2. Continued.

Source of variation	**N**	**Mean ± S.E.**
Location		***
Bako	28230	79.3 ± 0.14 [a]
Debre Zeit	15815	80.5 ± 0.26 [b]
Calving year		***
1980	3183	83.1 ± 0.36 [c]
1981	3040	83.8 ± 0.35 [abc]
1982	2842	79.9 ± 0.36 [e]
1983	2263	78.1 ± 0.38 [f]
1984	1565	74.6 ± 0.44 [g]
1985	1709	84.2 ± 0.42 [ab]
1986	2200	80.1 ± 0.38 [e]
1987	1951	78.3 ± 0.39 [f]
1988	1697	80.2 ± 0.42 [e]
1989	616	83.7 ± 0.65 [abc]
1990	3157	79.8 ± 0.30 [e]
1991	1920	75.2 ± 0.38 [g]
1992	2073	81.4 ± 0.37 [d]
1993	2162	84.5 ± 0.37 [a]
1994	3131	78.8 ± 0.31 [f]
1995	3480	83.3 ± 0.29 [bc]
1996	3302	80.4 ± 0.36 [e]
1997	2609	80.2 ± 0.33 [e]
1998	2145	69.4 ± 0.37 [h]
Interactions		
Model * data type		***
IG (b = 1) x Daily	1287	85.7 ± 0.48 [e]
IG (b = 1) x Weekly mean	1287	88.6 ± 0.48 [d]
IG (b = 1) x Weekly total	1287	88.6 ± 0.48 [d]
IG (b = 1) x Fortnight mean	1287	90.6 ± 0.48 [c]
IG (b = 1) x Fortnight total	1287	90.7 ± 0.48 [c]
IG (b = 1) x Monthly mean	1285	93.2 ± 0.48 [b]
IG (b = 1) x Monthly total	1285	93.2 ± 0.48 [b]
IG (b ≠ 1) x Daily	1264	65.6 ± 0.48 [o]
IG (b ≠ 1) x Weekly mean	1274	71.0 ± 0.48 [l]
IG (b ≠ 1) x Weekly total	1274	70.7 ± 0.48 [l]

Table 2. Continued.

Source of variation	**N**	**Mean ± S.E.**
IG (b ≠ 1) x Fortnight mean	1277	75.6 ± 0.48 I
IG (b ≠ 1) x Fortnight total	1277	75.2 ± 0.48 ij
IG (b ≠ 1) x Monthly mean	1277	82.3 ± 0.48 g
IG (b ≠ 1) x Monthly total	1277	82.3 ± 0.48 g
Exp x Daily	1144	60.7 ± 0.48 p
Exp x Weekly mean	1166	64.5 ± 0.52 o
Exp x Weekly total	1164	64.4 ± 0.51 o
Exp x Fortnight mean	1184	67.8 ± 0.51 mn
Exp x Fortnight total	1182	67.6 ± 0.51 n
Exp x Monthly mean	1188	72.8 ± 0.51 k
Exp x Monthly total	1187	72.8 ± 0.51 k
Pexp x Daily	1262	69.1 ± 0.51 m
Pexp x Weekly mean	1270	74.3 ± 0.49 ij
Pexp x Weekly total	1270	74.2 ± 0.48 jk
Pexp x Fortnight mean	1272	78.6 ± 0.48 h
Pexp x Fortnight total	1272	78.6 ± 0.48 h
Pexp x Monthly mean	1278	84.2 ± 0.48 f
Pexp x Monthly total	1278	84.2 ± 0.48 f
IP x Daily	1285	79.3 ± 0.48 h
IP x Weekly mean	1207	89.3 ± 0.48 d
IP x Weekly total	1287	88.8 ± 0.48 d
IP x Fortnight mean	1286	91.7 ± 0.48 c
IP x Fortnight total	1286	91.1 ± 0.48 c
IP x Monthly mean	1286	95.5 ± 0.48 a
IP x Monthly total	1286	95.4 ± 0.48 a
Sire breed x model		***
Friesian crossbreds * IG (b = 1)	4320	90.4 ± 0.27 de
Friesian crossbreds * IG (b ≠ 1)	4286	76.4 ± 0.27 j
Friesian crossbred * Exp	4012	70.5 ± 0.28 l
Friesian crossbred * Pexp	4279	79.0 ± 0.27 h
Friesian crossbred * IP	4318	91.6 ± 0.27 ab
Jersey crossbred * IG (b = 1)	1665	90.4 ± 0.46 cde
Jersey crossbred * IG (b ≠ 1)	1635	75.9 ± 0.47 j
Jersey crossbred * Exp	1487	68.8 ± 0.49 m
Jersey crossbred * Pexp	1632	78.7 ± 0.47 h

Table 2. Continued.

Source of variation	**N**	**Mean ± S.E.**
Jersey crossbred * IP	1665	91.5 ± 0.46 [abc]
Simmental crossbred * IG (b = 1)	1001	89.3 ± 0.56 [ef]
Simmental crossbred * IG (b ≠ 1)	988	74.7 ± 0.56 [k]
Simmental crossbred * Exp	886	69.4 ± 0.59 [lm]
Simmental crossbred * Pexp	985	77.8 ± 0.56 [hi]
Simmental crossbred * IP	999	92.7 ± 0.56 [a]
Boran * IG (b = 1)	488	89.4 ± 0.72 [def]
Boran * IG (b ≠ 1)	484	69.5 ± 0.73 [lm]
Boran * Exp	379	58.9 ± 0.82 [n]
Boran * Pexp	782	74.5 ± 0.73 [k]
Boran * IP	488	87.9 ± 0.72 [fg]
Horro * IG (b = 1)	1531	90.9 ± 0.51 [bcd]
Horro * IG (b ≠ 1)	1527	76.8 ± 0.51 [ij]
Horro * Exp	1451	68.4 ± 0.52 [m]
Horro * Pexp	1524	78.0 ± 0.51 [hi]
Horro * IP	1533	86.9 ± 0.51 [g]
Parity *model		***
1 x IG (b = 1)	1562	89.1 ± 0.44 [cd]
1 x IG (b ≠ 1)	1540	71.2 ± 0.44 [l]
1 x Exp	1309	60.7 ± 0.49 [o]
1 x Pexp	1541	73.4 ± 0.44 [k]
1 x IP	1562	91.1 ± 0.44 [ab]
2 x IG (b = 1)	1546	88.6 ± 0.46 [d]
2 x IG (b ≠ 1)	1522	75.6 ± 0.48 [ij]
2 x Exp	1440	67.3 ± 0.46 [n]
2 x Pexp	1513	78.7 ± 0.46 [f]
2 x IP	1544	90.1 ± 0.43 [bc]
3 x IG (b = 1)	1799	89.2 ± 0.43 [cd]
3 x IG (b ≠ 1)	1794	75.7 ± 0.45 [ij]
3 x Exp	1704	69.2 ± 0.43 [m]
3 x Pexp	1787	78.3 ± 0.43 [fg]
3 x IP	1799	89.4 ± 0.45 [cd]
4 x IG (b = 1)	1592	90.2 ± 0.45 [bc]
4 x IG (b ≠ 1)	1579	74.5 ± 0.48 [k]
4 x Exp	1445	68.2 ± 0.45 [mn]

Table 2. Continued.

Source of variation	**N**	**Mean ± S.E.**
4 x Pexp	1588	77.5 ± 0.45 [gh]
4 x IP	1593	90.2 ± 0.50 [bc]
5 x IG (b = 1)	1190	91.6 ± 0.50 [a]
5 x IG (b ≠ 1)	1180	74.7 ± 0.52 [jk]
5 x Exp	1106	68.9 ± 0.50 [m]
5 x Pexp	1179	76.9 ± 0.50 [ghi]
5 x IP	1190	90.7 ± 0.49 [ab]
6 x IG (b = 1)	1316	91.6 ± 0.49 [a]
6 x IG (b ≠ 1)	1305	76.3 ± 0.51 [hj]
6 x Exp	1211	68.9 ± 0.49 [m]
6 x Pexp	1294	80.2 ± 0.49 [e]
6 x IP	1315	89.3 ± 0.49 [cd]
Calving season * model		***
Gana x IG (b = 1)	1869	89.5 ± 0.41 [b]
Gana x IG (b ≠ 1)	1855	76.1 ± 0.41 [g]
Gana x Exp	1735	70.7 ± 0.43 [I]
Gana x Pexp	1846	785 ± 0.42 [f]
Gana x IP	1869	90.9 ± 0.41 [a]
Birra x IG (b = 1)	2050	88.4 ± 0.41 [c]
Birra x IG (b ≠ 1)	2007	68.8 ± 0.41 [j]
Birra x Exp	1759	63.4 ± 0.44 [k]
Birra x Pexp	1995	73.0 ± 0.41 [h]
Birra x IP	2049	88.9 ± 0.41 [bc]
Bona x IG (b = 1)	2140	91.2 ± 0.39 [a]
Bona x IG (b ≠ 1)	2123	73.3 ± 0.39 [h]
Bona x Exp	1906	62.4 ± 0.42 [k]
Bona x Pexp	2131	77.0 ± 0.39 [g]
Bona x IP	2140	89.3 ± 0.39 [bc]
Arfasa x IG (b = 1)	2946	91.1 ± 0.35 [a]
Arfasa x IG (b ≠ 1)	2935	80.5 ± 0.35 [e]
Arfasa x Exp	2815	72.4 ± 0.37 [h]
Arfasa x Pexp	2930	81.8 ± 0.35 [d]
Arfasa x IP	2945	91.4 ± 0.35 [a]
Model * Location		***
IG (b = 1) x Bako	5777	89.8 ± 0.26 [b]

Table 2. Continued.

Source of variation	N	Mean ± S.E.
IG (b = 1) x Debre Zeit	3228	90.3 ± 0.46 [ab]
IG (b ≠ 1) x Bako	5711	74.9 ± 0.26 [e]
IG (b ≠ 1) x Debre Zeit	3209	74.5 ± 0.47 [e]
Exp x Bako	5258	65.1 ± 0.27 [g]
Exp x Debre Zeit	2957	69.3 ± 0.49 [f]
Pexp x Bako	5708	77.9 ± 0.26 [d]
Pexp x Debre Zeit	3194	77.2 ± 0.49 [d]
IP x Bako	5776	89.1 ± 0.26 [c]
IP x Debre Zeit	3227	91.2 ± 0.47 [a]

Means in a column within a group with different superscripts vary significantly ($p < 0.001$)

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Estimated model parameters of incomplete gamma and inverse polynomial functions and comparison of the model's lactation yield prediction potential in zebu and crossbred cattle

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Abstract

The study was conducted to estimate model parameters of Incomplete Gamma (IG) (b=1) and Inverse Polynomial (IP) functions of a lactation curve and the models lactation yield prediction potential based on milk data from Bako Agricultural Research centre and Debre Zeit Research Station. The models were fitted to weekly total milk data of indigenous and crossbred cows. Five model parameters ("a", "c", "A_0", "A_1" and "A_2") of the two models, estimated from regression of weekly total milk data on weekly interval from calving, were analysed for the effects of genetic and non-genetic factors. Based on the estimated model parameters for each cow, lactation yield was predicted and the deviation of the predicted from the actual yield estimated. The predicted lactation yield and percent deviation of the predicted from the actual lactation milk yield were analysed using the General Linear Model. The overall least square mean values of "a", "c", "A_0", "A_1" and "A_2" were 2.559 ± 0.01, 0.103 ± 0.001, 0.379 ± 0.024, -0.076 ± 0.007 and 0.006 ± 0.001, respectively. All parameters were significantly ($p < 0.001$) affected by sire breed and calving year. Besides, calving season ($p < 0.001$) and parity of the cow (at least $p < 0.05$) significantly affected "a" and "c" only. Crossbred cows had significantly ($p < 0.001$) higher "a" and "A_1" and lower "c", "A_0" and "A_2" values than the indigenous breeds. Horro, as a sire breed, had significantly higher "a", "A_0" and "A_2" and lower "A_1" than Boran cows but not in the value of the parameter "c". Crossbred cows, however, were not significantly different among each other in the values of all parameters. Cows that calved in 1989 had significantly ($p < 0.001$) the highest "a"(2.750 ± 0.097), "A_2" (0.019 ±

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0.004) and "c" (0.132 ± 0.009), while the highest values of "A_0" (1.01 ± 0.11) and the lowest "A_1"(-0.238 ± 0.03) were recorded for cows that calved in 1987. Significantly ($p < 0.001$) highest values of "a" (2.543 ± 0.023) and "c" (0.115 ± 0.002) were obtained for cows that calved during Arfasa (short rainy season). The lowest values of "a" (2.156 ± 0.031) and "c" (0.102 ± 0.003) were recorded for cows in the first parity ($p < 0.001$). The parameter "c" showed a linear trend with an increase in parity order. The overall mean actual lactation milk yield, and lactation milk yield predicted from IG (b = 1) and IP are 1522.3 ± 17.18, 1540.3 ± 15.91 and 1360.9 ± 110.9 kg, respectively. The IG (b = 1) over-predicted the overall least square mean lactation milk yields by about 2.2 ± 2.33 % while the IP under-predicted least square mean lactation milk yield by 15.5 ± 9.61 %. The IG (b = 1) over-predicted least square mean lactation yields by 1.1 to 5.0% for all sire breeds, dam breeds, locations and parities, while the IP under-predicted least square mean lactation yield of all sire breeds except Horro and that of both dam breeds and locations. The significantly ($p < 0.001$) highest deviation was recorded for Horro cows (5.0 ± 0.69 %) compared to the other sire breeds. Comparison of dam breeds, locations and parities indicated that the percent deviation was significantly ($p < 0.05$) higher for Horro than Boran cows (3.4 vs 1.1%); for Bako than Debre Zeit herd (3.1 vs 1.5 %) and for cows in later than earlier parities. In the case of the IP, significantly ($p < 0.05$) highest deviation was observed for Boran cows (190.9 ± 50.9 %) compared to the other sire breeds. From this study it can be concluded that the IG (b = 1) better fitted to the weekly total milk data and enabled prediction of lactation milk yield with minimum biased compared to the IP and could be recommended for fitting to the lactation data of indigenous and crossbred cows of the study areas.

Keywords/phrases: Lactation curve, model, incomplete gamma, inverse polynomial

Introduction

A mathematical model of the lactation curve provides summary information on milk production, which is useful in making management and breeding decisions. Different studies (Wood, 1969; Madalena *et al.*, 1979; Rowlands *et al.*, 1982; Papajcsik and Bodero, 1988; Sherchand *et al.*, 1995; Perochon *et al.*, 1996; Olori *et al.*, 1999) have been conducted on lactation curves, and mathematical functions have been derived to describe these lactation curves. The usefulness of any mathematical model depends on how well it can mimic the biological process of milk production and adjust for factors affecting it. The objective of modelling lactation curves is to fit a mathematical function that can predict the yield on each day of lactation with minimum error. This can be used as a basis for decisions to cull or retain breeding stock (Papajcsik and Bodero, 1988; Sherchand *et al.*, 1995). Besides, the shape of the curve indicates to the dairy producer the needed changes in feeding management.

In a previous work done to compare the fitness of five models to lactation data of indigenous and crossbred cows, Gebregziabher *et al*. (2003b) selected the IG (b = 1) ($Y_N = AN^b \exp(-cN)$) and IP ($Y_N = N (A_0 + A_1N + A_2 N^2)^{-1}$) for their better fitness and practical applicability for data from both indigenous and crossbred cows. These models have a total of five parameters ("a", "c", "A_0", "A_1" and "A_2"). The parameter "ln(A)" or "a" in the IG (b = 1) is defined as "the scale of production" (Wood, 1972) or "initial milk production" (Madalena *et al.*, 1979) while "c" represents the rate of change in the declining phase of lactation curve (Yadav *et al.*, 1977). The parameter "a" is a scaling factor which is responsible for lowering or raising the lactation curves and will not change the general shape of the lactation curve (Batra, 1986), but "c" influences the shape of the lactation curve (Yadav *et al.*, 1977). In the IP model the parameters measure the rate of increase to peak production ("A_0"), the average slope of the lactation curve ("A_1") and the rate of decline after the peak yield is attained ("A_2"). In this study model parameters of the selected functions, which enable to construct lactation curve equations, are estimated and analysed for the effects of genetic and non-genetic factors on these parameters. Besides, the models power to predict lactation yield was compared.

Materials and Methods

The study was conducted based on existing data from Bako Agricultural Research Centre of Oromia Agricultural Research Institute and Debre Zeit Research Station of the International Livestock Research Institute (ILRI). Details of the two centres climatic condition, livestock management, breeding and health care are reported in previous works (Gemechu, 1992; Gebregziabher and Mulugeta, 1996). Lactation data of pure Horro and Boran and their F_1 crosses with Jersey, Friesian and Simmental exotic sire breeds were used for the study. The two models used for this study are IG (b = 1) with two parameters ($Y_N = AN^b \exp(-cN)$ b = 1; Papajicsik and Bodero, 1988) and IP ($Y_N = N (A_0 + A_1N + A_2 N^2)^{-1}$; Nelder, 1966). In the models "Y_N" represents weekly total milk yield recorded at week "N" interval from calving. The models were fitted to weekly total milk data using the regression procedure of the Statistical Analysis System (SAS, 1999). The IG (b = 1) was transformed to its linear form using a natural logarithmic transformation before fitting to the data, while the IP was not transformed. Five model parameters, two ("ln(A)" or "a" and "c") from the IG (b = 1) and three ("A_0", "A_1" and "A_2") from IP functions were estimated and analysed for different fixed effect using the General Linear Model (GLM) of the Statistical Analysis System (SAS, 1999). The GLM included fixed effects of sire and dam breed, location, calving season and year. Detailed descriptions of these fixed effects are presented in Gebregziabher *et al.*(2003a). Using the estimated model parameters obtained from each lactation, lactation milk yield was predicted for each cow. Then the predicted and actual lactation yields, lactation length and percentage deviation of predicted from the actual lactation milk yield were calculated and analysed for the effects of different factors.

Results

The overall least square mean values of "a", "c", "A_0", "A_1" and "A_2" were 2.559 ± 0.01, 0.103 ± 0.001, 0.379 ± 0.024, -0.076 ± 0.007 and 0.006 ± 0.001, respectively (Table 3). All parameters ("a", "c", "A_0", "A_1" and "A_2") were significantly ($p < 0.001$) affected by sire breed and calving year (Table 1) while the effect of calving season ($p < 0.001$) and parity of the cow ($p < 0.05$) were significant only for the parameters "a" and "c". Crossbred cows had significantly ($p < 0.001$) higher "a" and "A_1" and lower "c", "A_0" and "A_2" values than indigenous breeds. Horro, as a sire breed, had significantly ($p < 0.001$) higher "a", "A_0" and "A_2" and lower "A_1" than Boran cows but not in the value of the parameter "c". Crossbred cows were not significantly different among each other in the values of all parameters. The lowest values of "a" (2.156 ± 0.031) and "c" (0.102 ± 0.003) were recorded for cows in the first parity ($p < 0.001$). The parameter "c" showed a linear trend with an increase in parity order. Significantly ($p < 0.001$) highest "a" (2.543 ± 0.023) and "c" (0.115 ± 0.002) were observed for cows that calved during Arfasa (short rain season). Cows that calved in 1989 had significantly ($p < 0.001$) highest "a"(2.750 ± 0.097), "A_2" (0.019 ± 0.004) and "c" (0.132 ± 0.009), while the highest values of "A_0" (1.01 ± 0.11) and the lowest "A_1"(-0.238 ± 0.03) were recorded for cows that calved in 1987 (Table 3).

The overall mean actual lactation yield, and lactation milk yield predicted from IG (b = 1) and IP are 1522.3 ± 17.18, 1540.3 ± 15.91 and 1360.9 ± 110.9

kg, respectively (Table 4). The IG (b = 1) over-predicted the overall lactation yields by about 2.2 ± 2.33 % while the IP under-predicted overall lactation yield by 15.5 ± 9.61 %. The IG (b = 1) over-predicted least square mean lactation yields by 1.1 to 5.0% for all sire breeds, dam breeds, locations and parities, while the IP under-predicted least square mean lactation yield of all sire breeds except Horro and that of both dam breeds and locations. In the IP case the percent deviations of predicted lactation yields from actual lactation yields were very high for almost all sources of variation indicating that the model is not good predictor of lactation yield. Analysis of Variance of the percent deviation obtained from IG (b = 1) indicated that it was significantly (at least $p < 0.05$) different among sire breeds, dam breeds, locations and parities. Significantly highest deviation was recorded for Horro cows (5.0 ± 0.69 %) compared to the other sire breeds. As a dam breed, the percent deviation was significantly higher for Horro than Boran cows (3.4 vs 1.1%). Similarly, higher deviation of predicted yield from actual yield was recorded for Bako herd than Debre Zeit (3.1 vs 1.5 %). Among the parities, the percent deviation was highest for cows in later than earlier parities. Similarly, the percent deviation of the predicted from actual lactation milk yield estimated from the IP was significantly ($p < 0.05$) affected by sire breed only. Significantly highest deviation was observed for Boran cows (190.9 ± 50.9 %) compared to the other breeds.

Table 1. Mean square from least square analysis of variance of "a" and "c" of the IG (b = 1) fitted to different data types

Source of variation	**IG (b =1)**		**Inverse polynomial**		
	"a"	**"c"**	**"A_0"**	**"A_1"**	**"A_2"**
Sire breed	17.6 ***	0.1 ***	40.4***	3.1 ***	0.02 ***
Calving season	2.9 ***	0.01 **	0.39NS	0.02 NS	0.0001 NS
Calving year	0.6 ***	0.01 ***	2.92***	0.2 ***	0.001 ***
Parity	3.5 ***	0.004 *	0.12 NS	0.01 NS	0.0001 NS
Error mean square	0.2	0.002	0.72	0.06	0.0003
Error df	1229	1229	1229	1229	1229
R2	37.2	19.6	21.8	20.7	20.1
CV (%)	15.8	40.2	223.4	317.7	282.7

Significance level *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$ NS = not significant

Table 2. Mean square from analysis of variance of percentage deviation of predicted lactation yield from actual lactation yield estimated from IG (b =1) and IP

Source of variation	IG (b =1)	IP
Sire breed	0.04***	407125.8 *
Dam breed	0.09***	20519.9 NS
Location	0.03*	450.6 NS
Parity	0.02*	-
Error mean square	0.007	127469.5
Error df	1368	1373
R2	9.5	1.2

Significance level *** = p < 0.001, ** = p < 0.01, * = p < 0.05 NS = not significant

Discussion

Sire breed, parity, calving season and year significantly ($p < 0.001$) affected the parameters "a" and "c" (Tables 1&3). Crossbred cows had significantly higher value of "a" and lower value of "c" than the indigenous breeds. This indicates that crossbred cows start their lactation at a relatively higher level of production and the rate of decline from peak production is slower compared to the indigenous breeds. The crossbreds, however, were similar in the value of the parameter "a" and "c" while the Horro had higher "a" value compared to Boran cows. Similar breed variations in the values of the parameters "a" and "c" have been reported from previous works (Yadav *et al.*, 1977; Madalena *et al.*, 1979; Rao and Sundaresan, 1982; Wood, 1980; Abubakar and Buvanendran, 1981; Batra, 1986; Barios *et al.*, 1996). These variations reported from different studies are related to breed differences in lactation yield. Crossbred cows had higher lactation yield (Table 4) and initial and peak milk yield (Gebregziabher *et al.*, 2003a) compared to the indigenous breeds. Higher yields are associated with higher values of "a".

The value of the parameter "c" obtained in this study is higher than what is reported by Madalena *et al.* (1979) for IG ($b \neq 1$) fitted to daily milk production and Collins-Lusweti (1991) for monthly and weekly total milk yields for Holstein Friesian and Jersey cows. Higher "c" value obtained in this study reflects faster rate of decline from peak yield in these cows compared to the reports of Collins-Lusweti (1991). The significant sire breed effects are related to additive gene contributions from the better milk production of exotic breeds. Besides, non genetic factors such as calving season and year and parity contributed to the lower "a" and higher "c" values obtained in this study compared to the reports of Collins-Lusweti (1991) due to their direct or indirect effect on the animals calving weight, body condition and energy reserve for milk production, which is in agreement to other reports (Abubakar and Buvanendran, 1981; Batra, 1986; Barrios *et al.*, 1996). The higher "c" value for the indigenous breeds (Horro and Boran) than the crossbred (Friesian, Jersey and Simmental) is a direct reflexion of shorter lactation length and low lactation yield obtained in this study (Table 4) and supported by previous works (Sendros *et al.*, 1987; Chernet *et al.*, 2000). Lactation length is negatively correlated with the parameter "c" (Rao and Sundarsun, 1981) and cows which had shorter lactation length, showed a quicker rate of decline from the peak ("c") resulting in lower persistency (Abubakar and Buvanendran, 1981) compared to cows with longer lactation length. Similarly, Yadav *et al.* (1977) reported that the rate of decline was high in Hariana and crossbreds but not in ¾ Friesian. The positive correlation of "a" value with lactation yield, peak yield and daily yield up to peak yield (Rao and Sundaresan, 1981), the lower values of "a" for cows which had shorter lactation length (Abubakar and Buvanendran, 1981) and positive phenotypic and genotypic correlations of peak milk yield with the parameter "a" (Shanks *et al.*, 1981) suggest that this coefficient could be used in genetic selection for high lactation yield.

The effect of calving season on the parameter "a" and "c" was significant (Table 1). Significantly (at least $p < 0.01$) higher "a" and "c" values were obtained for cows that calved during Arfasa (short rainy season). This is related to the availability of feed and condition of the cows at calving. The amount of milk produced by an animal is derived from immediately accessible metabolites en route through the physiological system and mobilization of body reserves (Wood, 1977). Thus, cows that calved during Arfasa (short rainy season) probably had a better body condition as a result of the steaming up which has taken place indoor during Bona (dry season), hence the cows were not exposed to severe feed shortage during the dry season. Similar calving season effect on the parameter "a" and "c" were reported by Rao and Sundaresan (1982) and Batra (1986). All these reports ascribed calving season variation to the high quality fodder during the later stages of lactation. In the study sites (Bako and Debre Zeit), cows that calved during Arfasa have a chance to exploit the good grazing condition of the pastures in Gana (wet season). Besides, those cows are in an advantage that steaming up takes place during the dry season, which can protect the animal from losing weight and condition at time of calving and during postpartum periods.

Parity of the cow significantly affected both “a” and “c”. The parameter “c” showed a linear trend with parity order (Tables 3) which is consistent with different reports (Yadav *et al.,* 1977; Shanks *et al.*, 1981; Rao and Sundaresan, 1982; Barrios *et al.,* 1996). The significantly ($p < 0.05$) lowest “c” value for cows in the earlier parities is related to higher persistency values reported for these cows than cows in the later parities. Similar trend was observed in Sahiwal and Friesian cows (Wood, 1968; Rao and Sundaresan, 1979). The parity difference obtained in this study is related to the maturity of the cows, and its ability to withstand the stresses of lactation and make use of available reserve energy for milk production (Wood, 1977). First lactation cows are undergoing a maturation process which leads in an increase in milk secreting cells with the advance in lactation that counter balances the normal decline in milk yield as the lactation progresses (Stanton *et al.*, 1992) compared to mature cows. Besides, Collins-Lusweti (1989, 1991) also attributed the parity effect to the difference in the rate of depletion of body reserves, in that mature cows use their body reserves much faster in the early stages of lactation which leads to higher “c” value than in heifers. Hence, lower “c” value for first parity cows than later parities resulted in flat lactation curves for first lactation cows than cows in later lactations (Wood, 1970).

The influence of calving year on the parameters “a” and “c” were significant (Table 1&3). The highest value for the parameter “a” and “c” were observed for cows that calved in 1989. Similar year effect was reported by Madalena *et al.* (1979) and Rao and Sundaresan (1979, 1981, 1982).

The effects of sire breed and calving year on “A_0”, “A_1” and “A_2” were significant ($p < 0.001$; Table 1&3). Similar calving year and breed effects were reported by Batra (1986) and Yadav and Sharma (1985). The effects of parity and calving season were not significant in this study, which is contradictory to the report of Batra (1986) and Yadav and Sharma (1985). The reasons for the significant breed difference in the values of the parameters “A_0”, and “A_2” are related to the breed differences in the parameters “a” and “c” discussed elsewhere in this paper. The highest value of “A_0” observed show faster rate of increase to peak and lower “A_0” indicates flatter lactation curves, which reflects slow rate of increase to peak production (Batra, 1986). Therefore, the higher "A_0" and "A_2" for indigenous than crossbred cows are explained by the shorter ascending phase and lower persistency index reported in Gebregziabher *et al*. (2003a). Kumar and Bhat (1979) reported good fit of the IP for lactations that started at lower level and peak earlier than average. Gebregziabher *et al*. (2003b) reported that the IG (b = 1) followed by IP best fit to lactation data of indigenous breeds. In the IG (b = 1), the parameter "b" which is the rate of increase to peak production is set to be one meaning that highest slop of the curve to peak or fastest rate of increase to peak. Similarly, the indigenous breeds had highest value of "A_0" (rate of increase to peak production) than the crossbred cows. In both models the data showed fast rate of increase to peak, which in other words means shorter ascending phase. Thus, this finding suggests that in case where there is no IG (b = 1) in the comparison as in the case of Kumar and Bhat (1979), the IP could be the best model to fit the data.

The IG (b = 1) over predicted (range 1.1 to 5%) lactation yields of all sire and dam breeds, locations and parities as shown in Table 4. Horro, both as a sire and dam breed, had significantly ($p < 0.001$) the highest deviation of predicted lactation yield from the actual lactation milk yield. Besides, the predicted lactation yield of Debre Zeit herds was closest to the actual yield compared to the Bako herds. Similarly, the highest deviation was recorded for cows in the sixth parity. The IP under predicted lactation yield of both indigenous and crossbred cows except Horro. Sire breed showed a significant difference in the the percentage deviation of the predicted from the actual lactation yield. Among the sire breeds, the percent deviation for Boran cows was significantly ($p < 0.05$) the highest compared to the other sire breeds. Singh *et al*. (1997) reported that the IP function under-estimated the milk yield in the first month and over-estimated yield from the second to fifth month, thereafter, the curve ran close to the average observed lactation curve. Sudarwati *et al.* (1995), however, reported that the IP to be more accurate in predicting the 305 days milk yield equivalent closer to actual yields with smaller bias percentage and error using partial records up to three months. In this study, however, the trend between the actual and predicted yield across the lactation periods was not considered. The lactation yield predicted from IP is lower and the deviation from the actual milk yield is higher than that of IG (b = 1).

Conclusion

From this study it can be concluded that

- The model parameters estimated for both lactation curve functions were affected by genetic (sire breed) and non-genetic factors such as cow parity, calving year and season and location.
- Crossbred cows had higher initial milk yield (higher "a") and lower rate of decline from the peak or persistent yield (lower "c" and "A2") and slower rate of increase to peak indicating longer days to peak or longer ascending phase (higher "A1") compared to indigenous breeds.
- The suitability of the two models for predicting lactation yields of indigenous and crossbred cows were evaluated. The IG (b = 1) was found to be a better predictor of lactation data of both indigenous and crossbred cows.

Table 3. Least square mean (± SE) "a", "c", "A_0", "A_1" and "A_2" estimated from fitting IG (b = 1) and IP functions for indigenous and crossbred cows

Source	**N**	**IG (b = 1)**		**N**	**IP**		
		"a"	**"c"**		**"A_0"**	**"A_1"**	**"A_2"**
Overall mean	1260	2.559 ± 0.01	0.103 ± 0.001	1260	0.379 ± 0.024	-0.076 ± 0.007	0.006 ± 0.001
Sire breed		***	***		***	***	***
Friesian crosses	605	2.705 ± 0.019 [a]	0.097 ± 0.002 [b]	605	0.233 ± 0.040 [c]	-0.036 ± 0.012 [c]	0.003 ± 0.001 [c]
Jersey crosses	233	2.644 ± 0.031 [a]	0.093 ± 0.003 [b]	233	0.228 ± 0.064 [c]	-0.038 ± 0.018 [c]	0.003 ± 0.001 [c]
Simmental crosses	140	2.679 ± 0.037 [a]	0.088 ± 0.004 [b]	140	0.092 ± 0.079 [c]	-0.0003 ± 0.022 [c]	0.001 ± 0.002 [c]
Boran	65	1.923 ± 0.052 [c]	0.129 ± 0.005 [a]	65	0.828 ± 0.108 [b]	-0.162 ± 0.031 [b]	0.013 ± 0.002 [b]
Horro	217	2.166 ± 0.029 [b]	0.138 ± 0.003 [a]	217	1.181 ± 0.061 [a]	-0.306 ± 0.017 [a]	0.022 ± 0.001 [a]
Season		***	**		NS	NS	NS
Gana(June - August)	264	2.451 ± 0.027 [b]	0.110 ± 0.003 [ab]	264	0.453 ± 0.058	-0.102 ± 0.017	0.009 ± 0.001
Birra (Sept.-Nov.)	289	2.332 ± 0.026 [c]	0.106 ± 0.003 [b]	289	0.531 ± 0.055	-0.107 ± 0.016	0.008 ± 0.001
Bona (Dec. – Feb.)	295	2.369 ± 0.025 [c]	0.105 ± 0.003 [b]	295	0.541 ± 0.053	-0.105 ± 0.015	0.008 ± 0.001
Arfasa (March – May)	412	2.543 ± 0.023 [a]	0.115 ± 0.002 [a]	412	0.519 ± 0.048	-0.120 ± 0.013	0.009 ± 0.001
Parity		***	*		NS	NS	NS
1	220	2.156 ± 0.031 [c]	0.102 ± 0.003 [c]	220	0.517 ± 0.064	-0.112 ± 0.018	0.009 ± 0.001
2	218	2.423 ± 0.031 [b]	0.107 ± 0.003 [bc]	218	0.503 ± 0.065	-0.102 ± 0.018	0.008 ± 0.001
3	250	2.489 ± 0.028 [ab]	0.107 ± 0.003 [bc]	250	0.556 ± 0.061	-0.121 ± 0.017	0.009 ± 0.001
4	220	2.482 ± 0.030 [ab]	0.111 ± 0.003 [ab]	220	0.503 ± 0.064	-0.103 ± 0.018	0.008 ± 0.001
5	165	2.535 ± 0.033 [a]	0.111 ± 0.003 [ab]	165	0.489 ± 0.071	-0.111 ± 0.020	0.009 ± 0.001
6	187	2.458 ± 0.032 [ab]	0.116 ± 0.003 [a]	187	0.496 ± 0.067	-0.103 ± 0.019	0.008 ± 0.001

Table 3. Continued.

Source	N	IG (b = 1)		N	IP		
		"a"	"c"		"A_0"	"A_1"	"A_2"
Calving year		***	***		***	***	***
1980	91	2.488 ± 0.046 ^{bcd}	0.106 ± 0.005 ^{bcde}	91	0.373 ± 0.09^{e}	-0.075 ± 0.02^{def}	0.007 ± 0.002^{cdef}
1981	87	2.492 ± 0.045 ^{bcd}	0.104 ± 0.005 ^{cdef}	87	0.296 ± 0.09^{e}	-0.056 ± 0.02^{ef}	0.006 ± 0.001^{cdef}
1982	83	2.427 ± 0.047 ^{bcdef}	0.111 ± 0.004 ^{abcd}	83	0.358 ± 0.09^{e}	-0.064 ± 0.03^{def}	0.006 ± 0.002^{cdef}
1983	63	2.466 ± 0.053 ^{bcde}	0.115 ± 0.005 ^{abc}	63	0.658 ± 0.11^{bcd}	-0.138 ± 0.03^{bcd}	0.009 ± 0.002^{bcde}
1984	41	2.264 ± 0.066 ^{gh}	0.114 ± 0.007 ^{abcd}	41	0.841 ± 0.13^{abc}	-0.174 ± 0.03^{abc}	0.012 ± 0.002^{abc}
1985	49	2.438 ± 0.059 ^{bcdef}	0.114 ± 0.006 ^{abcd}	49	0.498 ± 0.12^{cde}	-0.107 ± 0.03^{bcdef}	0.009 ± 0.002^{bcdef}
1986	63	2.364 ± 0.052 ^{defgh}	0.112 ± 0.005 ^{abcd}	63	0.951 ± 0.11^{ab}	-0.183 ± 0.03^{ab}	0.011 ± 0.002^{abcd}
1987	56	2.368 ± 0.055 ^{defgh}	0.113 ± 0.006 ^{abcd}	56	1.010 ± 0.11^{a}	-0.238 ± 0.03^{a}	0.017 ± 0.002^{a}
1988	50	2.398 ± 0.058 ^{bcdefg}	0.102 ± 0.006 ^{cdef}	50	0.545 ± 0.12^{cde}	-0.129 ± 0.03^{bcde}	0.009 ± 0.002^{bcde}
1989	18	2.750 ± 0.097 ^{a}	0.132 ± 0.009 ^{a}	18	0.636 ± 0.20^{bcde}	-0.233 ± 0.05^{ab}	0.019 ± 0.004^{a}
1990	90	2.521 ± 0.046 ^{bc}	0.124 ± 0.005 ^{a}	90	0.611 ± 0.09^{cde}	-0.161 ± 0.02^{abc}	0.013 ± 0.002^{ab}
1991	53	2.311 ± 0.058 ^{efgh}	0.102 ± 0.006 ^{cdef}	53	0.398 ± 0.12^{de}	-0.065 ± 0.03^{def}	0.005 ± 0.002^{def}
1992	58	2.441 ± 0.056 ^{bcdef}	0.118 ± 0.006 ^{ab}	58	0.344 ± 0.11^{e}	-0.073 ± 0.03^{def}	0.008 ± 0.002^{bcdef}
1993	61	2.387 ± 0.055 ^{cdefg}	0.113 ± 0.005 ^{abcd}	61	0.376 ± 0.11^{de}	-0.070 ± 0.03^{def}	0.006 ± 0.002^{cdef}
1994	91	2.243 ± 0.047 ^{h}	0.100 ± 0.004 ^{def}	91	0.404 ± 0.09^{de}	-0.074 ± 0.03^{def}	0.006 ± 0.002^{cdef}
1995	100	2.456 ± 0.043 ^{bcde}	0.099 ± 0.004 ^{def}	100	0.206 ± 0.09^{e}	-0.022 ± 0.03^{f}	0.003 ± 0.001^{f}
1996	66	2.397 ± 0.054 ^{cdefg}	0.0.97 ± 0.006 ^{def}	66	0.503 ± 0.11^{cde}	-0.088 ± 0.03^{cdef}	0.005 ± 0.002^{def}
1997	75	2.543 ± 0.051 ^{ab}	0.097 ± 0.005 ^{ef}	75	0.347 ± 0.11^{e}	-0.054 ± 0.03^{ef}	0.004 ± 0.002^{ef}
1998	65	2.297 ± 0.054 ^{fgh}	0.092 ± 0.005 ^{f}	65	0.349 ± 0.112^{e}	-0.054 ± 0.03^{ef}	0.005 ± 0.002^{ef}

Means in a column within a group with different superscript vary significantly (*** = p < 0.001; ** = p < 0.01, * = p < 0.05 NS = not significant)

Table 4. Least square mean lactation yield (LY), lactation length (LL), predicted lactation yield (PY) and percentage deviation of predicted yield (%D) estimated from fitting the IG (b = 1) and IP to weekly total milk data

	N	LY	LL	N	IG (b = 1)		IP	
					PY	% D	PY	% D
Overall mean	1415	1522.3 ± 17.18	305.2 ± 2.32	1380	1540.3 ± 15.91	-2.2 ± 2.33	1360.9 ± 110.49	15.5 ± 9.61
Sire breed						***		*
Friesian crossbreds	684	1700.8 ± 29.08	318.2 ± 3.92	671	1714.9 ± 26.74	-1.7 ± 0.39 [a]	1459.9 ± 183.54	15.3 ± 15.96 [a]
Jersey crossbreds	276	1652.9 ± 46.55	313.2 ± 6.28	276	1655.0 ± 42.89	-1.6 ± 0.62 [a]	1692.6 ± 297.38	3.9 ± 25.87 [a]
Simmental	159	1820.1 ± 58.29	321.6 ± 7.86	159	1820.2 ± 53.62	-1.1 ± 0.78 [a]	1654.4 ± 371.7	11.7 ± 32.33 [a]
Boran	75	478.2 ± 79.57	234.7 ± 10.74	53	527.7 ± 85.35	-2.0 ± 1.25 [a]	68.1 ± 586.1	190.9 ± 50.9 [b]
Horro	221	707.9 ± 51.78	248.9 ± 6.98	221	713.1 ± 47.52	-5.0 ± 0.69 [b]	743.3 ± 329.5	-10.8 ± 28.66 [a]
Dam breed						***		NS
Boran	795	1440.2 ± 31.53	299.2 ± 4.25	760	1432.6 ± 30.30	-1.1 ± 0.44 [a]	1164.3 ± 208.02	47.9 ± 18.09
Horro	620	1103.8 ± 42.66	275.4 ± 5.75	620	1139.8 ± 40.19	-3.4 ± 0.59 [b]	1083.1 ± 278.1	36.5 ± 24.19
Location						*		NS
Bako	907	1321.8 ± 25.76	287.3 ± 3.47	894	1341.3 ± 25.53	-3.1 ± 0.37 [a]	1110.6 ± 176.18	41.2 ± 15.32
Debre Zeit	508	1222.2 ± 49.53	287.3 ± 6.68	486	1231.1 ± 46.82	-1.5 ± 0.68 [b]	1136.7 ± 322.73	43.2 ± 28.07
Parity						*		
1	256	976.8 ± 44.51	288.8 ± 6.00	252	962.9 ± 41.47	-1.1 ± 0.61 [c]		
2	251	1291.0 ± 46.96	297.3 ± 6.33	244	1280.5 ± 44.58	-1.9 ± 0.65 [bc]		
3	286	1412.4 ± 44.17	294.2 ± 5.96	282	1430.4 ± 41.55	-2.5 ± 0.61 [abc]		
4	248	1439.2 ± 46.57	295.9 ± 6.28	243	1447.5 ± 43.86	-1.8 ± 0.64 [bc]		
5	177	1341.6 ± 52.54	275.4 ± 7.09	173	1372.3 ± 49.21	-2.9 ± 0.72 [ab]		
6	197	1167.9 ± 50.89	272.2 ± 6.87	186	1223.3 ± 48.86	-3.6 ± 0.71 [a]		

Means in a column within a group with different superscript vary significantly (*** = $p < 0.001$; * = $p < 0.05$)

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Study on Reproductive Efficiency of Boran and its Crosses at Holetta Research Farm: Effect of genotype, management and environment

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Abstract

Reproductive data obtained during 1989-1999 from nine genetic groups, originated from local Boran cows, and their crosses with Friesian and Jersey were studied on 1025 records at Holetta Research Center. Least squares means for number of services per conception (NSC) for all genetic groups was 1.72 $\pm$ 0.14. Year of conception affected ($P<0.001$) NSC. The total conception rate (CR) of the herd was 76%. Among cow genetic group the NSC tended to decrease with increasing exotic blood level. Hence, the highest NSC (2.06) were required for Boran cows and the lowest for5/8 Jersey-Boran /5/8 JBO/ (1.37). Friesian- Boran /F_1FBO/ andF_1Jersey-Boran /F_1JBO/ required 1.74 and 1.65 NSC respectively.

Least squares means for days open till conception (DOC) was 181 $\pm$20 and was affected by genetic group and year of calving ($P<0.05$). Boran cows had 34 days longer days open than the F_1 crosses. The shortest mean value for DOC was found for the 3/4 Jersey-Boran (3/4JBO) (121 days) followed by 5/8 Jersey-Boran/ 5/8JBO/(123 days), F_1 Jersey- Boran (F_1JBO) (143 days) and F_1 Friesian- Boran /F_1FBO/ (144 days) while 5/8 Friesian-Boran (5/8FBO) cow had the longest (221 days).

Least squares mean pospartum anoestrus interval (PPAI) was 149 $\pm$ 21 days. Longest anoestrus interval was recorded for 5/8Jersey-Boran/5/8FBO/cows (188 days) while the shortest (114 days) was for3/4JerseyBoran/3/4JBO/. F_1 Friesian Boran/F_1 FBO/ and F_1 Jersey Boran / F_1 JBO/ required 115 and 121 days respectively. Generally, Jersey crosses were superior in reproductive efficiency than Friesian crosses. 5/8 Jersey-Boran /5/8 JBO/ and3/4Jersey Boran /3/4JBO/ crosses manifested better reproductive performance than the rest.

The estimated least square means NSC shows seasonality, Cows bred during the dry, short and main rainy seasons required 1.55, 1.47 and 1.87 services per conception, respectively.

Keywords: Reproductive Efficiency, Breed, Borana, Friesian and Jersey inheritance.

Abbreviation: AI, Artificial insemination; BO, Boran; CR, Conception rate; CV, Coefficient of variation; DF, Degree of freedom; DOC, Days open to conception; DS, Dry season; FBO, Friesian-Boran; F_1, First generation crossbred; F_2 , Second generation /inter se mating/crossbred; HARC, Holetta Agricultural Research Center; JBO, Jersey-Boran; LRS, Long rain season; N , Number of observation; NM , Natural mating; NSC, Number of service per conception; MS, Mean square; PPAI, Post partum anestrus interval; SE, Standard error; SP, Service period; SRS, Short rain season.

Introduction

Economic return from milk production is maximized with a calving interval of 12 months, a dry period of approximately 60 days and days open of 85 days. It has been reported that a 12-month calving interval (85 days open) can be achieved with a 45-day voluntary waiting period, 70% estrous detection efficiency and 60% conception rate (Radostits *et al.*, 1994). However, calving interval in Ethiopian Zebu range from 12 to 24 months (Mekonnen and Goshu, 1987; Kiwuwa *et al.*, 1983, Azage *et al.*, 1981) which varies among breeds and animals within a breed. A daysopen of 248.4, 211.1, 253.0 for Boran, Horro and Barka cattle respectively has been reported (Azage *et al.*, 1981).

Although crossbreeding and/or upgrading of cattle in Ethiopia has been done for last 30 years the performance and adaptability of crossbred cattle have not yet been clearly described. Comprehensive information on factors influencing the reproductive performance is, however, scanty under tropical conditions. Thus, in this study an attempt was made to investigate the genetic factor affecting the reproductive effeciency of indigenous Boran cows and their crosses with Jersey and Friesian Sires at the Holetta Agricultural Dairy reasearch Farm, west of Addis Ababa, Holetta, Ethiopia.

Crossbreeding has long been practised in country to bring about the desired genetic change quickly, to combine the high productivity of exotic and better adaptability of indigenous breeds in the crossbreeds.

Low pregnancy rate to Artificial Insemination (AI) in most African countries is attributed to poor semen quality, semen handling procedures, inadequate insemination skills, poor oestrus detection and wrong time of insemination, (Mukasa- Mugerwa *et al.*, 1991a).

Study at ILCA (1988) indicated that improving the management status of Zebu and their crosses increased the reproductive performance. It is obvious that improved management combined with the right genotype bring a substantial change in livestock productivity. However, the choice of genotype in combination with proper management remains a challenge in many African countries. Therefore, it was the objective of this study to analyse data on reproductive performance of Boran and its crossbred at the Holetta Research farm.

The objectives of this study were to evaluate the effect of genotype, management and environment on reproductive traits for number of service per conception (NSC), conception rate (CR), days open till conception (DOC), service period (SP), and postpartum anestrus interval (PPAI) between Boran and its Holstein-Friesian and Jersey crosses and to examine the effect of mating season, year and parity on conception in the above genotype.

Materials and Methods

Description of the study area

The data for the study was obtained from a long term cattle crossbreeding experiment of Dairy Breeding Program of the Ethiopian Agricultural Research Organisation (EARO) at Holetta Research Center which is located in the Central highlands of Ethiopia, 45 kms West of Addis Ababa. The Holetta Farm is located at an altitude of 2400 m.a.s.l. It receives an annual rainfall of 1100 mm and the area is characterized by mild subtropical weather with minimum and the maximum temperature ranges from 5 to 10 and 18.7 to 24.0^{0}C respectively. The rainfall pattern is bimodal, with a short rainy period from February to April and a long rainy season from June to September. The long dry season lasts from October to January. The predominant soil type is vertisol. Sufficient area of natural pasture is available for grazing and forages were grown for haymaking at the center. The vegetation cover consists mainly of annual legumes and perennial grass species. The pastures, dominated by *Hyparrhenia*, *Andropogon* and *Trifolium* species, were of moderate quality. The dam breed considered for this study were Boran, Friesian-Boran, Jersey-Boran and the sire breeds were Friesians and Jersey.

Reproductive traits

The reproductive traits studied were conception rate to first service (percent of cows confirmed pregnant to first service), days open (the period from calving to date of effective service), Service period (the period from first service to conception), Postpartum anoestrus interval (the period from calving to first services)

Genotypes

The Breed and crossbred groups used in the study were Zebu (Borana),F_1 crosses of 50% *Bostaurus* X 50% *Bos indicus*(½ Friesian ½ Borana -F_1FBO and ½ Jersey ½ Borana-F_1JBO), F_2 interse mating (½ Friesian ½ Borana -F_2FBO and ½ Jersey ½ Borana -F_2JBO),F_2 backcrosses to ¾ *Bos taurus* (5/8 Friesian 3/8 Borana -F(2(FBO) and 5/8 Jersey3/8 Borana -J(2(JBO), and F_2 backcrosses -75% *Bostaurus* (3/4 Friesian 1/4 Borana -F(FBO) and 3/4 Jersey1/4Borana -J(JBO).

Herd management

All calves were weighed at birth and identified by ear tag. Calves were separated at birth and were reared artificially using bucket feeding. Calves were kept in-doors in individual pens and were offered concentrate and hay starting 2 weeks after birth. Calves were allowed up to a maximum of 2 kg of concentrate per day and hay ad-libitum until weaning (3 months). Station born heifers were first mated on their third cycle of estrous. Special treatment was given to pregnant cows and heifers. They were separated into maternity pens at night during the last two months of gestation and supplemented with 2 kg of concentrate. Cows were milked twice daily by hand milking without the presence of their calves. Milking cows were managed under a loose -housing arrangement and fed native grass-hay indoors. Heifers and dry cows however were run on pasture during the daytime and supplemented with hay and concentrate in the evening. At times, milking cows were also run on pasture whenever shortage of grass-hay was encountered. During milking, however, cows were supplemented with balanced concentrate (Noug Cake with wheat middling and wheat bran) at the rate of 1kg per 2kg of milk produced.

All animals were vaccinated for Rinderpest, Foot and Mouth disease, Anthrax, Pasteurolsis, Blackleg and Contagious Bovine Pleuropneumonia (CBPP). Animals were also drenched and sprayed for internal and external parasites at regular intervals.

Heat detection was done twice a day once early in the morning (6-8 AM) and late after noon (5-6 PM). Animals observed in heat were bred either naturally or inseminated with frozen semen at 7 AM or 3 PM depending when an animal observed in heat. Those which were bred but not returned to oestrus were checked for pregnancy after two months, and if confirmed to be pregnant they were separated from the herd and kept indoor in the maternity paddock from 7 months pregnancy stage limited grazing in near by paddocks. The cows were weighed every month.

In this study to account breed difference nine genetic groups were made based on the blood levels. These were Boran; F_1, F_2, 5/8 and 3/4 of Friesian-Boran and Jeresy-Boran. Since management system varied between years, it was grouped into two periods to account for these variations. These are 1989 to 1996 (period I) and 1997 to 1999 (period II), during which continuous calving herd and natural synchronised breeding programs were followed respectively. Based on climatic data and pasture condition of Holetta, months of the year were grouped into three seasons covering the short rainy (February - April), the long (big) rainy (June-September), and the dry season (October-February and May).

Data Collection

Data used for this study were cover the period of 1989 and 1999 years on reproductive performance of Boran and their Friesian and Jersey crosses. The study focussed on the reproductive efficiency that is NSC, DOC, SP and PPAI. A total of 319 cows with 1025 records have been involved in the study. Out of these 100 were Boran (Zebu origin) and 219 were crosses (121 Friesian and 98 Jersey). Number of records were 270 for Boran and 755 for crosses, (409 Friesian and 346 Jersey). The genetic groups considered for this study were, Local Zebu (Boran) and crossbreeds with 1/2, 5/8 and 3/4 blood levels of Friesian and Jersey. All available records on the above traits were included, with the exception of some missing data, which resulted in unequal number of records for the various traits.

Individual record of each cow and each calving were used for analysis. These include date of calving, date of estrus, time of heat detection, time of insemination (service), date of effective service, service type, parity and pregnancy.

Statistical analysis

The data on reproductive efficiency traits collected from 1989 to 1999 at the research station were used for the analyses. The fixed effects used were genetic group(B), season(S), year(Y) parity(P), and mating type(Q). The data were analysed using general linear model SAS (1999). ($Y_{ijklm} = \mu + B_i + S_j + Y_k + P_l + Q_m + BS_{ij} + SQ_{jm} + e_{ijklm}$) where: Y_{ijklm} = the observation of m^{th} mating of the l^{th} parity of the k^{th} year of the j^{th} season of the i^{th} genetic group. $(BS)_{ij}$= interaction of breed and season.$(SQ)_{jm}$= interaction of season and mating type. e_{ijklm} = random error

Results and Discussion

Number of Services per Conception (NSC)

The overall mean NSC was 1.72 $\pm$ 0.12 (Table 1). The genetic group had no significant effect on the number of services required per conception. However, a clear trend of improvement in fertility with increasing levels of exotic inheritance was observed (Table1). The NSC tended to decrease with increasing exotic blood (Friesian and Jersey) inheritance among cow breeds. Hence, the highest NSC (2.06) was found for Boran cows and the lowest (1.34) for $5/8^{th}$ Jersey cows. This is in agreement with Mekonnen and Goshu (1987) who evaluated the reproductive performance of Zebu, Friesian and their crosses, and reported that the number of services required per conception tended to decrease with increasing Friesian inheritance among dam breeds. The genetic group did not show any significant difference on NSC. The result obtained showed that Boran cows needed more NSC than the F_1 crossbred cows. Similarly, Azage (1981) reported that in Zebu and their crosses with temperate breeds the NSC decreased in the crosses as compared with the Zebu breeds. Mekonnen (1987) also reported a non-significant effect of breed group on NSC.

The cross breed in general, and the5/8 Jersey crosses in particular, required relatively few number of services per conception than cows with 1/2 and 3/4 exotic inheritance. The lowest mean number of services required per conception was obtained for 5/8JBO crosses (1.34 $\pm$ 0.25). This could be due to small size of Jersey crosses that might make them compatible to the local environment as compare to Friesian.

The NSC showed seasonality that cows bred during the dry, short and main rainy seasons required 1.55, 1.47 and 1.87 services per conception, respectively. Thus, cows inseminated during the short rainy seasons required low NSC than those cows bred in the main rainy season. This could be due to the favorable climatic conditions and abundant green fodder availability. This is in agreement with Azage (1981) and Swensson et al (1981) who have reported that NSC increases in the dry months of the year as compared with rainy months of the year in Zebu and their temperate crosses in Ethiopia.

Mean NSC of 1.72 did not differ between all factors considered in the model except for year differences which required more NSC in the later years (1.77) than the earlier ones (1.45). This could be due to the change of composition of the herd due to purchase of foundation herd (Boran) in 1996 and the management of the farm. Among the factors considered, only year of conception had significant ($p<0.01$) influence on NSC. The relatively fewer number of services required per conception during the dry and short rainy seasons were consistent with the higher total number of conception in these two seasons. Saeed *et al.* (1987) also reported that Kenana cows in the Sudan required fewer numbers of services per conception. In general, the NSC in the present study was 1.5 to 2.5 which is within the range given for crossbred cows in Ethiopian (Azage Tegegne et al, 1981; Kebede Beyene, 1992; Kiwuwa *et al.*, 1983). However, considering this in relation to the long PPAI (149days) and DOC (181days) the value may not reflect the true breeding status of the herd as many heats may not have been detected by herd attendants.

Days Open till conception (DOC)

The overall mean days open was 181$\pm$ 20 days (Table 1). The result in this study showed that days open till conception (DOC) was significantly influenced ($p < 0.05$) by genetic group. Boran cows had 34 days and 35 days longer days open than the F_1- Friesian and F_1-Jeresy crosses respectively (Table 1). Similarly, Azage Tegegne (1981) reported that crossbred cows had 81.8 days shorter DOC than the local cows. Different researchers have reported a variable results for DOC. Tesfu Kassa (1990) who studied on crossbred and Zebu cows in the central highlands of Ethiopia reported mean intervals for calving to conception of 157.8 and 199.8 days, respectively. Estimates of days open till conception have been reported to range between 130 to 300 days in Zebu and crossbred cows under management conditions of research centers in Ethiopia (Azage Tegegne et al., 1981). The longer interval for the Boran cows could have been due to difficulties in heat detection, occurrence of silent heat and short oestrus period which is a common phenomena among Zebu cows (Trail *et al.* 1971).

Table 1. Mean and standard error (SE) for DOC, PPAI, SP, NSC, and CR of breed group in Holleta Agricultural Research Center (HARC).

Variable Genetic grp	DOC (days) Mean + SE	PPAI (days) Mean + SE	SP (days) Mean + SE	NSC (No.) Mean + SE	CR (%) Mean + SE
BOxBO	178 ± 22[b] (161)	123 ± 19 [b] (162)	65 ± 10.83 (266)	2.06 ± 0.12 (267)	70 ± 3.12 (267)
BOxF	144 ± 19[b] (73)	115 ± 17 [b] (73)	30 ± 10.31 (109)	1.74 ± 0.14 (109)	72± 3.55 (109)
BOFxBOF	183 ±22[ab] (108)	150 ± 19[ab] (112)	36 ±10.47 (171)	1.58± 0.12 (169)	78 ±3.27 (169)
5/8BOF	221 ± 30[a] (41)	188 ± 26[a] (42)	48 ± 14.23 (64)	1.78± 0.18 (64)	79 ±4.66 (64)
3/4BOF	164 ± 26[ab] (39)	146 ± 22[ab] (41)	38± 13.66 (137)	1.52 ±0.18 (57)	80 ±4.74 (57)
BOXJ	143 ± 23[b] (89)	121 ± 20[b] (93)	30+_12.50 (57)	1.65 ± 0.14 (119)	76± 3.48 (119)
BOJXBOJ	185 ±23[ab] (79)	160 ± 20[ab] (81)	37 ± 11.09 (117)	1.59 ± 0.13 (137)	78± 3.48 (137)
5/8BOJ	123 ±41[b] 21)	119 ± 36[b] (21)	37 ±22.81 (33)	1.34 ± 0.24 (33)	87± 6.29 (33)
3/4BOJ	121 ± 34 [b] (20)	114 ± 30[b] (20)	21 ± 17.58 (31)	1.41 ± 0.25 (31)	83± 6.46 (31)
Mean	181	149	38	1.72	76
SE	20	21	11.25	0.14	3.12
F-test	*	*	ns	ns	ns
C.V (%)	64.56	68.44	197.68	68.36	38.96

* P<0.05 ns = not significant SE = Standard error C.V.= Coefficient of variation
Means with in the same column followed by the same letter or no letter do not differ from each other significantly (P>0.05)
Figures in parenthesis are number of records.

The reproductive performance of the F_1-Friesian crosses was better than either the pure Boran, F_2, 5/8th or 3/4th Friesian crosses. The poor reproductive performance of 3/4th crosses was consistent with studies in the tropic. McDowell, (1985) and Kebede Beyene(1992), suggested that the management level at the station was just good enough to support animals below 3/4 Friesian inheritance. The wide variability in reproductive performance among the year-groups (periods) indicate that, genetic group evaluation needs to be done under more or less uniform management over years. Significant ($p<0.05$) effect of breed group was also observed in DOC and PPAI. The estimated least squares means presented in (Table 1) showed that first crosses, especially, the F_1 Boran Friesian crosses (F_1FBO) had shorter DOC and PPAI than crossbred with F2, 5/8 and 3/4 exotic inheritance. The fact that crossbreds with higher levels of exotic inheritance had longer DOC is in accordance with the reports of El-Amin *et al.* (1986). However ¾ Boran-Jersey crosses had shorter periods of DOC and PPAI than crossbreds with F_1 F_2, and 5/8 exotic inherence.

Days open was significantly influenced ($p < 0.05$) by year of calving but not by season of calving and parity (Tables 2,3 and 4). The non significant effect of season on DOC was substantiated with the result of Azage (1981). The long DOC (179 days) observed in the first period (continous calving herd) could be due to non availability of proper feed through out the year related to reduced dry period feed supplementation. In other words cows calving during the first period (1989/1996) had longer days open (179 days) while those calving in the second period (1997/1999) had shorter interval (146 days) (Table 4). The long days open in the first period was due to delay in the onset of estrus as reflected by the longer PPAI 157 $\pm$ 14.7 days (Table 4). Which may be due to shortage of proper feed through out the year. The long PPAI due to improper nutrition was also substantiated by (Tesfu Kasa and Azage Tegegne , 1992; Tesfu Kasa *et al.,* 1993).

Service period (SP)

The over all mean service period found in this study was 38 $\pm$ 11.25 days (Table1). However there is no significance difference among the genetic group. The estimated least squares means showed that first crosses, especially, the F_1 Boran x Friesian crosses (F_1FBO) had shorter service period than crossbreds of F_2 and 5/8 exotic inheritance. However, ¾ Boran x Jersey crosses had shorter service period (21 $\pm$ 17.58) than crossbreds of F_1, F_2 and 5/8 exotic inherence. This could be due to the small size of Jersey crosses that the Jersey, being small breed, may be more drought resistant and may have a better feed efficiency as compared to the other large breeds and besides, may adapted better to warmer regions (Kebede Beyene et al., 1977, Kebede Beyene, 1992). In dairy cattle, extended service period and long DOC would increase the generation interval, limiting the number of lactations and calves born. On the other hand, too short a service period and a DOC would adversely affect the length of lactation. It is therefore necessary that an optimum service period and DOC commensurate with normal reproduction so that economic production could be obtained.

Service period was longest in long rainy season (47 days), shortest in dry season (19 days) calvers and intermediate in short rainy season (45 days) (Table 2), but differences between means were not significant. The long SP in long rainy season calvers may be attributed to scarcity of green fodders since the grazing are protected for hay making and water logging problemes. Khidir *et al.*, (1979) reported that well grown Kenana heifers, fed diets short of green fodders, suffered silent heat and they attributed it to vitamin A deficiency. These arguments lend support to the conclusion that SP may be reduced through better environmental and feeding management. These include adequate supply of green or conserved fodders in long rainy season, and /or addition of vitamin A supplement, and protection from heat in dry seasons (Alemu Gber Wold, 1984). In the hot season night grazing may be an attractive practical proposition.

Table 2. Effects of parity on reproductive parameters of dairy cows at Holetta Agricultural Research Center.

Parity	DOC (days) Mean ± SE	PPAI (days) Mean ± SE	SP (days) Mean ± SE	NSC (No.) Mean ± SE	CR (%) Mean ± SE
1	172 + 18.1	148 ± 15.7[a]	41± 10.21	1.67 ± 0.12	76 ± 3.00
	(179)	(181)	(260)	(258)	(258)
2	174 + 18.2	154± 15.8[a]	44 ± 10.50	1.60 ± 0.12	78 ± 3.03
	(147)	(150)	(225)	(226)	(226)
3	141 ± 19.9	116 ± 17.3[b]	42 ± 10.99	1.77 ± 0.13	77 ± 3.22
	(91)	(93)	(166)	(166)	(166)
4	152 + 21.7	120 ± 18.9[b]	45 ± 12.32	1.58± 0.14	80 ± 3.78
	(66)	(67)	(236)	(99)	(99)
5$^+$	146 ± 19.0	124 ± 16.5[b]	44 ± 10.65	1.67 ± 0.12	76 ± 3.12
	(148)	(154)	(98)	(237)	(237)
F-test	ns	*	ns	ns	ns

* P< 0.05 ns = not significant
Mean within the same column followed by the same letter or no letter do not differ from each other significantly (P>0.05)
Figures in parenthesis are number of records. 5$^+$ Five and above

Post partum anestrus interval (PPAI)

Post partum anestrus interval is a variable determining both calving interval and calving rate of a herd. The result obtained demonstrated that PPAI was significantly affected by genetic group (P<0.01). The overall mean of

149 $\pm$ 21 days for PPAI found in this study (Table 1) was longer than the ideal interval of 45 days (Lamming and Darwash, 1989). An interval of 97.5 $\pm$ 25.1 days for resumption of postpartum ovarian activity was reported for crossbred dairy cows under smallholder management conditions in Ethiopia (Tesfu Kasa, 1990). On the other hand the average PPAI for crossbred dairy cows was 53.5 $\pm$ 32 days and ranged from 22 to 135 days as reported by (Yoseph Mekasha, 1999). The estimated least squares means presented in this study showed that first crosses, especially, the F_1 Boran Friesian crosses (F_1FBO) had shorter PPAI than the F_2, 5/8 and 3/4 exotic inheritance. The fact that crossbreds with higher levels of exotic inheritance had longer PPAI is in accordance with the reports of El-Amin *et al*. (1986). However ¾ Boran-Jersey crosses had shorter PPAI than crossbred with F_1, F_2 and 5/8 exotic inherence. This could be due to the fact that Jersey has a better adaptability to the local environment as compared to Friesian. Kebede Beyene *et al (*1977) reported that Jersey, being a small breed, might be better in feed efficiency and adaptation to local environment as compared to the large exotic breeds.

The result obtained demonstrated that PPAI was significantly affected by parity and period of calving (Tables 2 and 4). Highly significant year effects ($p<0.001$) were observed on PPAI. Cows calving during the first period (1989/1996) had the longest PPAI (157 days) while those calving in the second period (1997/1999) had the shortest interval (118 days) (Table 4). The possible reasons for shorter intervals recorded for PPAI during period II (1996-99) could be in response to improvement of management and seasonal breeding practices carried out at the center. Parity exerted a significant effect ($p<0.05$) on PPAI. This has indicated a clear trend of decreasing after the first and second parity (Figure1). Thus, PPAI decreased from 160 days in first parity to 122 days 3rd parity. Further, it was observed that the trend beyond the 3rd parity was increasing PPAI.

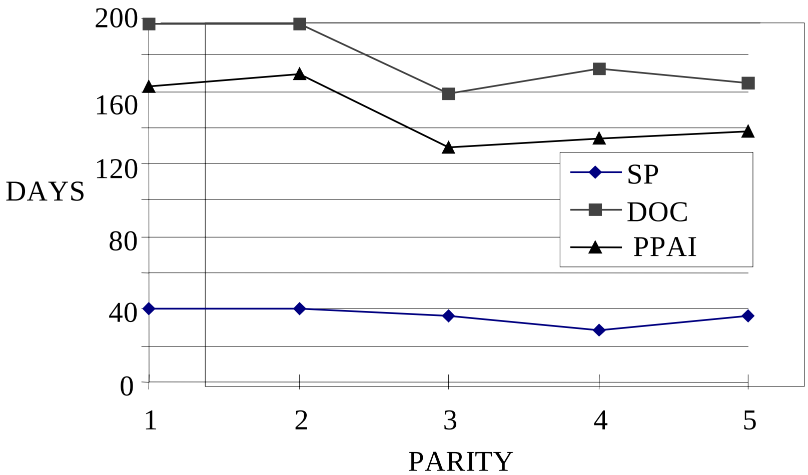

Figure 1. Effect of Parity on DOC, PPAI and SP

In the first parity cows, the causes of this age related difference in PPAI be due to delayed resumption of ovarian activity after calving. This may be a result of longer resting period they need to recover from stress of parturition and to cope with the increased nutritional demand of growth and lactation during their early ages. After the 5± parity the changes are attributed to age related delays. This latter increasing number of PPAI could be due to the tendency of older and weaker cows to take longer time to recover from effects of the past pregnancy and lactation stresses. This is in disagreement with (Enyew Negussie, 1992) who also stated that the trend of decreasing DOC over the parities up to 5th parity and gradual increase there after. For the dairy herd experiencing long PPAI exceeding 40-45 days, nutritional program should be examined (Ferguson, 1996), as the quality and quantity as well as feeding systems have a far reaching impact on the reproductive performance of dairy cows. The longer PPAI observed in this study could be the result of poor feeding management.

Seasonality of conception (SC)

The total of 986 conceptions of all genetic groups over the period of ten years 1989 to 1999 showed that the highest percentage (total of 42 %) occurred in the short rainy season between February and April. The percentage of conceptions for the other two seasons, long and dry season ranged from 25 % (June to September) to 33 % (October to January). This is in agreement with Michalak *et al* (1983) who have indicated that 54.3 % of all conception occurred between January and May at Abernossa farm in Southern Rift Valley of Ethiopia. The highest percentage of conceptions per month during the short rainy season is consistent with the results reported in Ethiopia (Michalak *et al.*, 1983; Makonnen and Goshu, 1987) and in Sudan (Saeed *et al.*, 1987). Michalak *et al* (1983) related the seasonality of conception to increase in day light hours that occurs in March in Ethiopia (Spring equinox). Also, other, workers (Plasse *et al.,* 1970; Makonnen and Goshu 1987) related elevated conception rates to months of high temperatures which also coincides with increase in day length. However, the above observation is in disagreement with the views of Hafez (1980) who concluded, after reviewing several studies that high temperature depresses conception rate and increases the number of services required per conception. Michalak *et al* (1983) showed that temperature, rainfall, and average day length (h) had variable effects on seasonality when considered singly but their combined effect accounted for 86-99 % of the variability in seasonality of conception in the high lands of Ethiopia. This seems to be true when the feed supply throughout the year is reasonably uniform. Otherwise rainfall distribution, through its effect on pasture growth and nutrition, could have an important influence on conception pattern (Wilson and Clarke, 1976). The reason for such a relationship and their possible uses in improving reproductive efficiency need to be studied.

Seasonality in quality and quantity of the fodder is closely related to the intake and digestibility of the feed and animal performance. During the rainy season pasture is abundant, and the quality, intake and digestibility of the pasture are high enough to meet maintenance, growth and reproductive requirements of the animals. In the dry season, both intake and digestibility are low and the available nutrients do not match the requirement of the animals. The ability of the animal to reproduce is highly affected by nutritional status and this could be improved through supplementation mainly during the dry season.

Season in general had no statistically significant effect on most of reproductive traits considered in this study. However, cows calved during the long rainy season showed lower conception rate than those calved during the short rainy and dry season. This could be due to seasonality in feed availability since cows calved during the main rainy season will have to pass most of their critical period in the long dry season. This is in agreement with the result (Mekonnen and Goshu, 1987; Eneyew Negussie et al 1999). Although the effect of season was not statistically significant, cows calving at the end of the dry and during the short rainy seasons had a relatively shorter DOC and PPAI than those calving during the main rainy season (Table 3). The main advantage of calving during this period is related to better nutritional status in the subsequent favorable months of the rainy seasons to meet the higher nutrient requirements of postpartum cows for maintenance, growth and lactation.

The possible reasons for shorter intervals recorded for both traits, DOC and PPAI, during period II (1997-99) (Table 4) could be improvement in management, and seasonal breeding practices carried out at the center. However, a marked increase was observed for the NSC during this period. The possible reasons for the observed annual variability and marked increase in the NSC could be either a bull effect or it could be due reproductive problem among the herd or it could be due to the change of composition of the herd and management.

Table 3. Effects of season on reproductive parameters of dairy cows at Holetta Agricultural Research Center.

Seasons	**Season of calving**			**Seasonal services**	
	DOC (days)	**PPAI (days)**	**SP (days)**	**NSC (No.)**	**CR (%)**
	Mean + SE	**Mean + SE**	**Mean + SE**	**Mean + SE**	**Mean + SE**
Dry season (Oct- Jan)	174 + 21 (367)	139 + 28 (378)	19 + 6.11 (576)	1.55 + 0.14 (325)	81+ 3.12 (325)
Short rainy season (Feb_ Apr)	129 + 29 (163)	108 + 25 (163)	45 + 14.62 (250)	1.47 + 0.14 (410)	83 + 3.58 (410)
Long rainy season (June- Sep)	185 + 32 (101)	166 + 28 (104)	47 + 16.00 (159)	1.87 + 0.17 (251)	71 + 4.45 (251)
F-test	ns	ns	ns	ns	ns

ns = not significant
Figures in parenthesis are number of records

Table 4. Effects of period (Year) reproductive parameters of dairy cows at Holetta Agricultural Research Center.

Pattern of calving	Season of calving			Seasonal services	
	DOC (days)	PPAI (days)	SP (days)	NSC (No.)	CR (%)
	Mean ± SE	Mean ± SE	Mean + SE	Mean ± SE	Mean ± SE
1989-96 (Continuos calving)	179 ± 15[a] (409)	157 ± 13[a] (418)	33 ±7.92 (530)	1.49 ± 0.09[b] (528)	81 ± 2.43[a] (528)
1997-99 (Seasonal calving)	146 ± 17[b] (222)	118 ± 14[b] (227)	41 ± 9.28 (455)	1.77 ± 0.09[a] (458)	75 + 2.52[b] (458)
F-test	*	***	ns	**	*

*** P <0.001 ** P <0.01 * P< 0.05 ns= not significant
Mean within the same column followed by the same letter or no letter do not differ from each other significantly (P>0.05)
Figures in parenthesis are number of records.

Conclusions

Therefore, this study concluded that if the reproductive efficiency of Boran cows is to be improved, cows must be genetically up-graded to the level 50%. There is also an indication that upgrading Boran cattle up to 75% exotic inheritance preferably with Jersey sires could be taken up at least for better reproductive efficiency provided the level of management is good enough to meet the relatively higher managerial demand of these animals. In general, the observed seasonal trend indicated an obvious advantage of planned seasonal breeding so as to avoid a decline in reproductive performance associated with the seasonal fluctuations. Therefore, it is suggested that under such environmental conditions, if animals are to be bred seasonally on consideration of reproductive performance alone, improved performance would be realized if mating is planned to take place during the wet months preferably just before the beginning of main rainy season. However more intensive studies on physiological parameters in Zebu cows need further investigation

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Abortion and Calf Mortality of Friesian-Boran Crossbred Cattle at Cheffa State Farm, Wollo, Ethiopia

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Abstract

Abortion and calf mortality of Boran-Friesian graded calves maintained at Cheffa state farm, Wollo, Ethiopia, were analyzed to interpret the effect of level of inheritance (1/2, 3/4, 7/8 and ≥15/16 Friesian), parity (1 to 9^+) and season (short rains, long rains and dry).The least squares mean for abortion was 17.6 ± 0.01% out of 2589 pregnancies and ranged from 9.9% for 1/2 breds to 37.7% for ≥ 15/16 breed groups. All the considered factors significantly affected abortions. The rate of abortion was much higher than the available reports and significantly higher for the later two grades. The prospective causes for abortion were not confirmed, but suspected to be associated either with diseases, abortifacient plants and genetic factors. The rate of female calf mortality was 29.9 ± 0.02% out of 1024 total female calves born and significantly affected only by breed group. There was a progressive increase of calf mortality from 3/4 to highest grade. The largest proportion of calves died was due to diarrhea, followed by cowdriosis and pneumonia. Stabilization of native inheritance and improving the level of management are preconditions for better performance at the farm.

Keywords: Abortion, Calf mortality, Friesian-Boran crosses, Cheffa state farm, Wollo- Ethiopia

Introduction

During the last three decades intensive infusion of Friesian inheritance into native breeds is going on in tropics with the sole aim of obtaining higher milk out put per cow. This has led to a serious situation of reduced genetic ability of graded calves to survive in tropical environment. In the tropics, the estimates of abortion ranged from 2.5% to 13.4 % (Vaccaro and Vaccaro, 1982; Mekonnen, 1987; Melaku, 1994) and calf mortality ranged from 3.0 to 29% (Mekonnen, 1987; Yimam, 1994; Zelalem *et al.*, 1997) among graded calves. Some of the causes of calf losses were calf scour (Abraham, *et al.*, 1992), pneumonia and inadequate feeding (Yimam, 1994). Brucellosis and moulds grown on reserved hay (Mekonnen, 1994), feeding poisonous plants, stress and starvation (CTA, 1996) cause untimely delivery. Under these health and physiological challenges the calves with higher *Bos taurus* blood were lost at higher rate (Mekonnen, 1987 & 1994 and Zelalem *et al.,* 1997).

In this paper, an attempt was made to quantify the abortion rate as affected by the level of *B. taurus* inheritance, parity state of dams and season of birth of calves. The female calf mortality rate based on age group and causes of death is also studied.

Materials and Methods

The study was conducted at Cheffa farm situated at 10° 55'N latitude and 39° 47'E longitude at an altitude of 1490 masl in Wollo Ethiopia. The three defined seasons in the area were short rains (February to May); long rains (June to September) and dry season (October to January). A bimodal rainfall pattern is thus the case with an annual average of 960 mm of which 32% falls in short rainy season. The average maximum and minimum temperature were 30.2 °C and 13.6 °C, respectively.

The herd was established in 1976 with Boran dams and pure Holstein-Friesian bulls. At the beginning animals were subjected to 24 hours grazing system. Starting from 1986, the grazing hours were arranged from 0200 hrs to 1800 hrs. Animals were allowed to graze in groups based on sex and age. Grazing land management was poor and affected by water logging, infested with noxious weeds and unpalatable annuals. Mating was natural during the study period. Traditionally made hay, alfalfa green and concentrate feed prepared from maize and noug cake were fed according to age, stage of pregnancy and milk yield. Calves were weaned from the dams immediately after birth and fed with colostrums for two days. During the first 45 days, calves were offered milk. A small quantity of concentrate was also provided with milk from 45 to 90 days and then weaned from milk. Vaccination against rinderpest, CBPP, anthrax and blackleg were given. Animals were dewormed for parasites and treated for other infectious and tick born diseases. However, this was continued at irregular interval. The calves of different age groups were housed in different pens of concrete floor and corrugated zinc sheet wall.

The data on abortion and female calf mortality were collected from 1976-1997. A total of 2589 and 1024 records were analysed for abortion and calf mortality from 602 cows. Pregnancies culminated below 260 days were considered as abortion. Those calves born dead or died within 48 hours of birth were taken as stillbirths. For calf mortality, the calves died after two days of birth to 12 months of age were included. Fixed effects studied were breed groups (1/2, 3/4 7/8 and 15/16 and above), parity and season of birth. The half grades were not considered for calf mortality since the fetus carried is 75%. Male calves were culled at earlier age and thus not included in the analysis of calf mortality. Diagnostic results of the Kombolcha Regional Laboratory, clinical case books and individual animal records were used. Some species of the natural pasture were identified in collaboration with the weed unit of Kombolcha Plant Health Clinic

Data were analyzed using the General Linear Model (GLM). Only breed group means were presented for stillbirth since the data set were not affected by any of the factors considered before or after square root transformation. Percentage data on abortion and calf mortality were analyzed after transformation and the final results were presented in original scale (Gomez and Gomez, 1984). Linear contrasts of least-squares means were computed to detect the significant difference within the variable group.

Results

Abortion

The overall percentage of abortion was 17.6 ± 0.01 and it increased to 22% of total pregnancy when stillbirth was included. The least squares means are presented in Table 1. Abortion was affected by breed group, parity and season. As the Friesian blood level increased from 1/2 to 15/16 so did rate of abortion from 9.9 to 37.7%. The rate of abortion was 12.0% for first calvers and increased 21 to 29% after the fourth parity. The abortion rate was highest during the long rainy season. On a separate analysis, the average abortion rate in the month of August was about 17%. Stillbirth was not affected by breed group, parity and season. The mean rates of stillbirth for 1/2, 3/4, 7/8 and higher groups were 3.0 ± 0.03, 4.1 ± 0.04, 4 ± 0.04 and 6.7± 0.06%, respectively.

Calf mortality

Overall mean of female calf mortality up to one year of age was 29.9 ± 0.02% (Table 2). Only breed group significantly affected calf mortality. Parity and season of birth had no significant effect. Calves with higher exotic blood died at a higher rate than lower groups before reaching the age of one year. Nearly, 49% of the calves with 15/16 and more Friesian blood died.

Mortality rates for breed group 3/4, 7/8 and 15/16 and above were almost similar during the first three months of life while for group 7/8 the rate was higher after six months of age (Table 3). The highest number of calves died was due to diarrhea followed by heart water and pneumonia. Furthermore, scrutiny of data revealed that diarrhea killed calves particularly between birth and four months of age (Table 4). Cowdriosis claimed more life when the calves were at the second quarter of their age and comparatively more calves of 7/8 and 15/16 grades and above crosses were died. The rate for pneumonia was almost similar in all the age groups. Streptotrichosis and certain physiological problems were serious between the fourth and eighth month of age.

Discussion

Abortion

The prenatal death is a significant loss associated with dairy enterprise. The rate of abortion (17.6%) estimated in this study (Table 1) is alarming and higher than the estimates of Vaccaro and Vaccaro (1982) for tropical cases; and, Mekonnen (1994) and Melaku (1994) under Ethiopian condition. The increased abortion with increase of *taurus* blood level could be due non compliance of better management as exotic inheritance is enhanced as well as the inability of these cows to overcome nutritional, environmental and disease problems. Similar results are on records incase of cross breeds of different developing countries (Singh *et al.,* 1987; Mekonnen, 1994). High rate of prenatal loss for older cows observed in this study support the fact that the ageing uterus reacts too slowly to the demands of the rapidly growing hybrid fetus and rapidly to the untimely stimulus initiating parturition (Hafez, 1993).

Serological tests of brucelosis undertaken at Cheffa state farm in 1988 using Serum Agglutination Test (SAT) and in 1993 using Rose Bengal Plate Test (RBPT) revealed that there were 22 and 22.6% positive reactors, respectively (Tariku, 1994). In this farm, one cow for every three cows aborted and 52% of the cases the cows aborted twice or more. Also, one cow for every seven cows gave stillborn calves and 22.3% of the cases the cows delivered two or more stillborn calves. Though positive reactors for brucellosis were high in the farm (Tariku, 1994), this alone can not be taken as main cause of abortions since in brucellosis majority of affected animals do not abort more than once. The existence of some estrogenous plants such as *Amarantaceae, Asteraceae, Cucurbitaceae, Euphorbiaceae, Fabaceae* and *Solanaceae* in the grazing area might caused fertility problems. Certain physiological stage of growth of these plants may be coincided to the late stage of long rainy season and might cause abortion as evidenced by occurrence of about 17% of abortion in the month of August.

Moreover, overgrazing during earlier season and drought may reduce the amount of palatable plants and thus allowing poisonous plants to multiply. Stagnant water which remained for a long time in the field was a good growing media for various types of algae which might further aggravated the death of the fetus. The genetic variability in resisting the effects of abortificient may be the cause of higher abortion rates noticed in the higher grades. Further, from farm records it was observed that the herd was affected by single or multiple infection of foot and mouth disease, anaplasmosis, anthrax and blackleg during the study period and different grades might have responded differently.

Calf mortality

The average calf mortality was found to be 29.9% and is higher than averages recorded in reports of Mekonnen, 1987; Nesru, 1997 and Zelalem *et al.,* 1997 except that reported by Yimam (1994) for pure Jersey breed which it self is unusually very high (62%). The calves with higher exotic blood died at a higher rate (Table 2) and the trend concords with the findings of Zelalem *et al.* (1997). This may be associated with increased demand for quality feed, management and health care. Higher mortality in higher grades might also be to increased susceptibility to diseases prevailing in the farm environment with the dilute of the local blood.

High percentage of female calve mortality as the level of inheritance increased (Table 3) might be poor response of this group of animals to that local environment. The death of many calves from diarrhea causing diseases could be as a result of inadequate feeding of colostrums and sanitation of the living quarter. Also, tick species of *A. coherence, A. gemma* and *B. decoloratus* were identified in this farm (Daniel, 1994). The Kombolcha Regional Laboratory identified *A. marginale* in 1980; *anaplasmosis* and *babesiosis* causing agents in 1988 and 1989; and, fasciola, paramphistomum, strongly species in 1984, 1986 and 1988 to 1990. Suspected cases of heart water, streptotricosis and bovine babesiosis were also observed in the clinical case books. Though no confirmatory diagnosis were established throughout the study periods, the above evidences strongly suggest that disease of various sets such as helminthes, protozoan infestation and external parasites are common in the study area. This indicates that the routine health care and management of calves was not to the level required. The largest proportion of calves died from cowdriosis after 120 days of age (Table 4) may be the contamination of the pasture by various tick species and other parasites. A good proportion of calves died with no obvious reason demands a thorough investigation.

Table1 Least squares means (S.E.) of abortion by breed group, parity and season of calving

Source	Conceived n	Abortion (%) Mean ± S.E.
Overall	2589	17.6 ± 0.01
Breed group		**
½	825	9.9 ± 0.06[d]
¾	1133	14.4 ± 0.12[c]
7/8	472	32.0 ± 0.27[b]
≥15/16	159	37.7 ± 0.26[a]
Parity		*
1	599	12.0 ± 0.12[e]
2	475	14.7 ± 0.14[de]
3	393	14.5 ± 0.12[e]
4	304	18.8 ± 0.15[cd]
5	250	25.6 ± 0.24[ab]
6	160	21.3 ± 0.18[bc]
7	141	22.7 ± 0.30[bc]
8	112	27.7 ± 0.20[a]
9+	155	25.2 ± 0.2[ab]
Season		*
Short rainy	741	14.8 ± 0.15[b]
Long rainy	780	21.3 ± 0.33[a]
Dry	1068	16.9 ± 0.20[b]

* = P < 0.05 ** P < 0.01

Within variable groups, means followed by the same letter do not differ significantly (P<0.05)

Conclusions

Abortion and calf mortality were a serious problem in this farm and the rate increased with blood level. Abortion may be associated with brucellosis, infectious diseases and abortifacient plants. However, in-depth scientific inquiry on the content of abortifacient agents, estrogenic factors and poisonous substances in natural plants and forages of pasture of lowland area. The largest proportion of calves died was due to diarrhea followed by cowdriosis and pneumonia reflects the farm hygienic conditions and management. Reliance on high grades over 3/4 Friesian blood carries a element of risk-genetic vulnerability of some traits in prevailing divergent environment. At the same time economically feasible standardization of repressible environment and timely application of animal husbandry skill is needed to harvest the genetic potentiality of exotic inheritance.

Table 2 Female calf mortality percentage among breed groups

Source	**n (born)**	**Mean ± S.E.**
Overall	1024	29.9 ± 0.02
Breed group		**
¾	368	19.8 ± 0.02[c]
7/8	458	28.8 ± 0.03[b]
≥15/16	198	51.0 ± 0.04[a]

*P < 0.05

Within variable groups, means followed by the same letters do not differ significantly (P < 0.05).

Table 3 Breed group and age wise distribution of number of female calf died

Breed group	**Total died (n)**	**Age group (days)**		
		3-120	**121-240**	**241-365**
¾	73	39	17	17
7/8	132	47	32	53
≥15/16	101	47	22	32

Table 4 Cause and age wise percentage distribution of total female calf mortality

Cause	**Age group (days)**			**Total (n) died**
	3-120	**121-240**	**241-365**	
Diarrhea	51.9	22.7	10.7	89
Cowdriosis	24.0	39.4	26.2	87
Pneumonia	10.6	10.6	11.7	33
Anthrax	6.7	-	15.5	26
Streptotrichosis	1.9	6.9	2.9	9
Indigestion	1.9	6.9	-	5
Unknown	3.0	13.5	33.0	57

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The Effects of Breed and Age of Chicken on the Amount of Faecal Excretion of *Eimeria* Oocystes and Mortality Rate Due to Coccidiosis

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Abstract

The effects of breed and age on faecal output of *Eimeria* oocystes and mortality rate due to coccidiosis was studied on 180 chickens from three breeds (60 each) namely; local (normal and necked-neck), Babcock (50% crossed with White leghorn) and White leghorns. The chickens were categorized into three groups, each again categorized into three subgroups each consisting 20 chickens from each breed. Identification and enumeration of *Eimeria* oocystes were made from fresh fecal samples and coccidiosis was diagnosed based on postmortem lesions and detection of the parasite's developmental stages from tissue smears. The overall mortality rate due to coccidiosis reported in this work was estimated to be 58%. The variation in mortality rate among the breeds was significant ($p< 0.01$); White leghorn was affected at higher rate (81.7%) compared to the Babcock (50%) and local breed (41.6%). Generally, a steady decrease in mortality rate over increasing age was reported during the study period ($r=0.5$). The variation in the amount of fecal excretion of *Eimeria* oocystes among the three breeds was significant ($p< 0.005$). WLh excreted relatively higher amount of oocystes compared to the other two breeds. Similarly, age of chickens significantly ($p<0.005$) influenced the amount of oocystes excreted in faeces. Keeping chickens of different breeds and ages in same house would favor the establishment of epidemic coccidiosis in a poultry farm. It was also recommended that resistance to coccidiosis was possible through genetic selection and that appropriate management of local chickens can help reduce incidence of the infection.

Key words. Breed/ Age/chickens/Eimeria oocyste/coccidiosis/ /mortality

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Introduction

In Ethiopia, the population of poultry significantly exceeds that of any other livestock species. According to the ministry of Agriculture, poultry population of the country is estimated to be around 53 million (about 40% of the total livestock population) (Technical Center for Agricultural and Rural Cooperation, CTA, 1997). Chickens are reared almost in all agro-ecological zones predominantly under traditional husbandry system and they constitute vital sources of household cash income and food. Poultry husbandry in an intensive system is also practiced by some urban and peri-urban dwellers.

Diseases are among the major constraints to poultry production in the country. However, information regarding epidemiology is inadequate.

Coccidiosis of chickens is caused by single-celled protozoan parasites that live in the epithelial lining of the intestine, and those affecting chickens are largely due to the species *Eimeria* (David, 1984). Though publications related to poultry coccidiosis in Ethiopia are absent, information obtained from some poultry farms (personal communication) suggested that it is the most prevalent and serious disease of chickens.

In most poultry farms in the country, chickens are usually maintained in same houses irrespective of their ages and breeds. This gives raise to persistent establishment of serious infectious diseases like coccidiosis and their causative agents in the farms. This paper, thus, describes the effects of keeping different breeds and ages of chickens in same house on the amount of faecal excretion of *Eimeria* oocystes and mortality rate due to coccidiosis at a poultry farm of Awassa College of Agriculture.

Materials and Methods

Study area

The study was carried out from May to September 1997 in a poultry farm of Awassa College of Agriculture, Debub University, Awassa town. Awassa is located 275km south of Addis Ababa, the capital of Ethiopia, at a latitude of 7^0 04'N and a longitude of $38^0$31'E and an altitude of 1700m above sea level. The area receives an annual rainfall of 900-1100 mm and temperature ranges from 10^0 to 30.5^0C.

Experimental Animals

Three breeds of chickens were used for this experiment. These were White leghorn, Babcock (50% crossed with White leghorn) and local strain (Normal and necked-neck). They were mainly kept for educational and research purposes. Chickens were housed in a deep floor system. Although not rat-proof, the houses were adequately ventilated through special ventilator openings of mesh-wire made. Feed and water were provided twice a day during morning and evening. Disease, in particular coccidiosis, is a major production constraint of the farm.

Collection of Faecal Samples

Approximately 5g Faeces was collected daily in petridish directly from the floor using spatula from at least four different places in each pen (Janssen pharmaceutica, 1990). The samples were collected fresh from normal as well as very thin and watery consistent excrements and made to contain as little litter as possible. Collected samples were soon transported to parasitology laboratory of the veterinary section of Awassa College of Agriculture for oocystes identification and enumeration.

Identification and Enumeration of Eimeria Oocystes

In laboratory, samples of each pen were thoroughly mixed to obtain representative samples from the chickens present and the examination reproducible. Oocystes identification and enumeration were made using modified MacMaster's technique (MAFF, 1982). Mean oocystes count of each week for each breed was then estimated from the daily counts. The number of oocystes in the samples was expressed in terms of oocystes per gram of faeces (OPGF).

Diagnosis of Coccidiosis and Estimation of Mortality Rate

Diagnosis of coccidiosis was made by autopsy of representative number of dying chickens and direct examination of the intestinal and caecal faeces for detection of the different developmental stages of the parasite. Daily mortality record, based on breed and age, was taken and the rate was then calculated for each week using a method described by Putt, *et al, (*1987).

Experimental Design

Day-old chickens (n=180) (60 chickens from each of the three breeds) were directly transferred from hatching room to a pre-emptied house. The chickens were categorized into three groups (G1, G2 and G3) and maintained in separate pens. Each group (n=60) again was categorized into three subgroups each consisting 20 chickens from each of the three breeds and maintained in sub spaces within each pen. This was made to avoid the potential effects resulting from variation in housing and management conditions. The house was uniformly supplied with light power and feeding and watering conditions were also made uniform for all the groups.

Statistical Analysis

The effects of breed and age of chickens on mean faecal output of *Eimeria* oocystes were assessed using analysis of variance (Systat version 7.0.1, SPSS Inc, 1997). Linear regression was used to estimate the trend of relationship between age and overall mortality of the infection and mean faecal oocystes counts. The degree of association between mortality of the infection and breed was assessed using chi-square independent test (Gupta, 1985). The coefficient of variations of mean oocystes count per gram of faeces for different age and group categories as well as the trend in the amount of oocystes output and mortality over age trend were assessed using descriptive statistics (Systat version 7.0.1, SPSS Inc, 1997)

Results

Table 1 shows mortality rate due to coccidiosis in the three breeds of chickens. Significant ($p<0.05$) variation in mortality rate was observed among the breeds. White leghorn (WLh) was affected at much higher rate (81.%) than local (41.6%) and cross- bred (50%) chickens. Again, comparing the overall mortality cases reported during the study period, WLh shared higher proportional mortality (47%) than Babcock (29%) and local (24%) breeds.

In this study, it was reported that more than half (58.3%) the chickens had died of Coccidiosis. The incidence was particularly higher (81%) in the age range between 5th to 10th weeks; the highest rate being 14.4% at the 5th week of age and declined steadily then after. No death case was reported after 13th week. The trend in mortality rate over an increasing age is shown in figure 2.

Table1. Mortality due to coccidiosis in White leghorn, Babcock x white leghorn and normal and necked- neck chickens at the poultry farm of Awassa college of Agriculture

Breed	Number examined	Death	Percent
Normal and necked–neck	60	26	41.6
Babcock x white leghorn	60	30	50
White leghorn	60	49	81.7
Total	180	105	58.3

$P<0.01$(significant)

The regression of overall mortality rate due to coccidiosis on increasing age is shown in figure 1. Generally, steady regression of mortality over increasing age was observed during the study period (R^2=0.2764), though the relationship appeared positive (r=0.525).

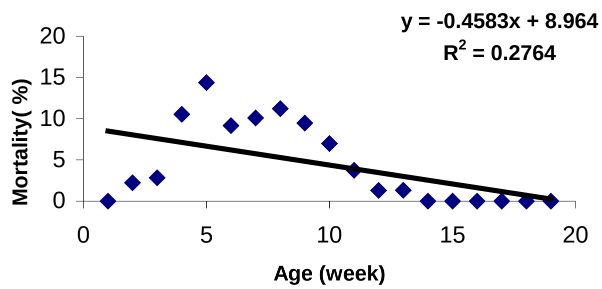

Figure 1.The regression of overall mortality due to coccidiosis over increasing age of chickens

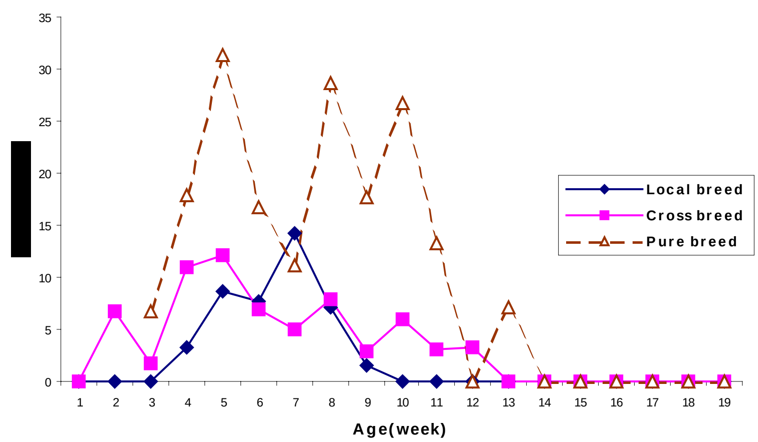

Figure 2. Trend in mortality rate over increasing age chickens.

Figure 3 shows linear relationship of mean faecal oocyste concentration and increasing age. Although the age mark at which the highest faecal concentration of oocystes was encountered and the concentration started to decline then after varied among the breeds, the linear relationship between the amount of oocystes output and age generally appeared negative (R=0.18).

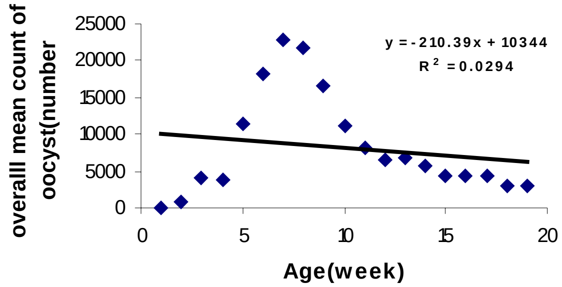

Figure 3. The regression of overall mean faecal oocyste out put over increasing age

Figure 4 shows trend in mean faecal out put of oocystes over an increasing age. Generally, the oocystes count sharply increased starting from the 2nd week and attained the highest count from 6th up to 9th week (about 47% of the overall oocyste concentration was encountered in this age range) and it started to decline steadily then after (The mean range of overall oocystes count was around 1.0290×10^4). No significant oocystes were recovered from faecal samples collected at the 1st week of the experiment. For local breed, faecal oocystes excretion was observed lately (around the 4th week) while crossbred and WLh started the excretion relatively at earlier time (around the 2 nd and 3rd week, respectively).

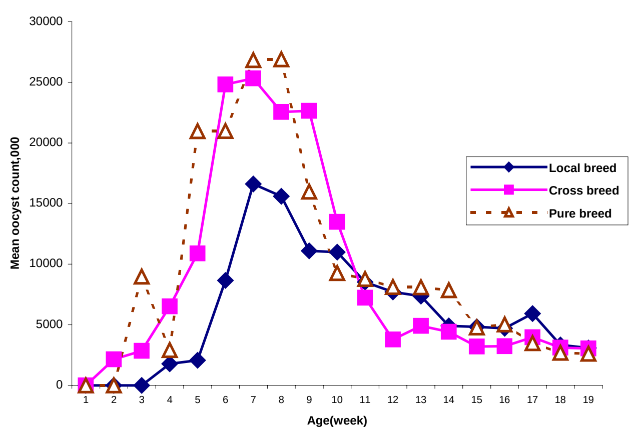

Figure 4. The trend in mean faecal output of *Eimeria* Oocystes over increasing age of chickens

The effects of breed and age of chickens on the amount of faecal excretion of *Eimeria* oocystes are shown in table 2. Significant ($p<0.005$) variation in faecal oocyste concentration was reported among the breeds WLh excreted relatively high amount of oocystes (37%) during the study period compared to low faecal output (28%) of local breed. Similarly, age had significantly (P<0.005) influenced the amount of oocystes excreted in faeces.

Table 2. Analysis of variance for the effects of breed and age of chickens on the amount of faecal output of *Eimeria* oocystes

Source	Sum-of-Squares	DF	Mean-Square	F-ratio	P
Breed	3.34099E+08	2	1.67050E+08	16.810	0.0002*
Age	7.92841E+09	18	4.40467E+08	44.323	0.0004**
Group	693.203	2	346.602	0.000	0.999***
Error	1.47078E+09	148	9937687.659		

*P<0.001, **P<0.001, ***p>0.5.

Table 3 shows coefficient of variation of faecal oocystes count of the three groups. Grouping of chickens didn't show any significant effect (p>0.5) on variation in oocystes count Likewise, oocystes count among the subgroups with in the three groups for each breed is insignificant.

Table 3. Coefficient of variation of mean faecal oocystes counts of the three groups

Breed	Group1	Group2	Group 3	Range	Sum	Mean	S.D	C.V
Local	6234.2	6225.4	6049.13	185.07	18508.73	6169.6	104.4	0.017
Cross	8730	8828	8999.7	269.7	26557.7	8852.6	136.5	0.015
Pure	39345.9	39430	40450.3	1104.3	119226.28	39742.0	614.7	0.015

Discussion

In this study, 58% overall mortality rate due to coccidiosis was estimated, though significant variation occurred among the breeds. Different researchers reported different mortality rates of coccidiosis under different management conditions. A flock mortality of 10% and 20% had been reported by Malcolm (1978). On the other hand, Edigar and Siebold (1964) reported mortality rate of 70% in an intensive farm. Soulsby (1982) also described that when young birds were placed on heavily contaminated litter, as high as 100% mortality could occur. This variation in mortality rate due to coccidiosis can be attributed, interalia, to pathogencity of the parasite involved, nature of the host (Soulsby, 1982) and difference in management system.

In this work, clinical and post mortem examinations of representative samples of birds revealed the predominance of *Eimeria tenella* and *Eimeria* *nicatrix* though the involvement of other species such as *Eimeria acervulina* was also evident. In fact, caecal and intestinal coccidiosis have been the most serious health problems of chickens in the poultry farm of the college (Arega, personal communication). This finding agrees with that of Soulsby, 1982; Malcolm, 1978; Gordon & Jordan, 1982 and David, 1984 who reported that *Eimeria tenella* and *Eimeria nicatrix* were the major pathogenic species in several outbreaks of coccidiosis despite the involvement of some other species as part of mixed infection.

Breed had significantly ($p<0.001$) influenced the amount of faecal oocystes output and mortality rate due to coccidiosis ($P<0.01$). Pure White leghorn was found having higher fecal oocystes concentration (37%) and more affected by the infection (81.7%) than were Babcock and local breeds. Susceptibility and resistance of different breeds and outbred lines of birds against coccidiosis had been reported by several researchers (Gordon&Jonson, 1982; Hamet & Merat, 1982; Johnson and Edgar, 1986 Bumstead & Millard, 1987; Ruff and Bacon, 1989; Albers &Verneigen, 1992). In agreement with the present observation, Pan and-van der laan, *et al,* (1998), in their experiment on the genetic resistance of different outbred lines of chickens against coccidiosis, showed that White Leghorn and its outbred lines are the most susceptible to the infection by coccidiosis compared to breeds like Fayoumi and Babcock. The amount of faecal oocystes excretion was highly correlated ($r=0.8$) with mortality rate of the infection suggesting that, compared to the rest breeds, White leghorn contributed more to the environmental contamination by oocystes and suffers from consequent mortality and chance of repeated infections by lethal dose of the viable *Eimeria* oocystes. This may suggest the fast multiplication rate of the parasite and its consequent pathogenic effects in this breed. This opinion supports the work of Gordon & Jonson, (1982) who argued that the variation in the output of faecal oocystes could be associated with the degree of resistance against the rate of asexual and sexual reproductive phases of the parasite and the presence degree of infection. In agreement with this fact, Malcolm (1978) and Gordon and Jonson (1982) also explained that the rate of reproduction and consequent pathogenic effects could be influenced by genetic make up of the host. On the other hand, the relative resistance of local breed to the infection may be partly attributed to frequency of exposure to the infection by oocystes as this breed has been maintained in the farm for longer time and it seems, therefore, that resistant population line has developed over time.

Age of chickens had influenced faecal oocystes output significantly ($P<0.001$) and was positively correlated ($r=0.5$) with mortality rate due to coccidiosis. The period during which the oocystes appeared in faeces and death commenced as well as the age marks at which these parameters attained the maximum level and started to decline then after were reported to vary among the three breeds. Nevertheless, a steady regressive relationship was observed between increasing age and the amount of faecal oocystes excretion and mortality rate. The highest count of faecal oocystes and mortality were reported between the age ranges of 6^{th} to 10^{th} weeks. This is comparable with the work of Jordan (1990) in which reported the highest oocystes count and mortality rate at around the age of 5^{th} to 8^{th} weeks and a negative relationship then after. Malcolm (1978) also reported that coccidiosis infection in chickens is usually common at around the age of 6^{th} week. Our finding, however, disagrees with that of Gordon and Jordan (1982) who argued that age resistance is not considered to be an important factor in susceptibility of chickens to coccidiosis.

Several factors could influence the nature of course of coccidiosis infection among which, immunity (Soulsby, 1982; Jordan, 1990) and viability and survival of oocystes on the ground are the most important. Different researchers at different times had described the importance of immunity in coccidiosis (Soulsby, 1982; Jordan, 1990; Qureshi *et al,* 1998; Pinard-van der laan, et al 1998). In agreement with the present observation, Soulsby (1982) and Malcolm (1978) stated that birds could develop resistance against coccidiosis infection with increasing age because of gradual exposure to the oocystes. Further more, it was reported that immunity could be acquired following the infection, although resistance may vary depending on the species and the number of subsequent re-infections (Soulsby, 1982; Malcolm, 1978). This supports our work in that mortality rate had started declining significantly at around the age of 7^{th} week and no mortality was reported 14^{th} week after. The role of parental immunity in protecting young birds from infection by coccidiosis should not be ruled out in this aspect.

In the present observation, oocystes excretion had continued through out the study period, though the amount gradually declined. This agrees with the observation made by Malcolm (1978) who reported that oocystes production usually declines following maximum production and clinical manifestation of the infection, though few might continue to appear for as long as 7 months.

The fact that no oocystes were detected in samples collected at early age (1 to 2 weeks) could be attributed to the species and nature of life cycle of the parasite. Malcolm (1978) described that the appearance of new generation of *Eimeria* oocystes is relatively late in the life cycle, usually a week after ingestion of sporulated oocystes. This is because the time required for completion of one prepatent cycle is at least seven days. On the other hand, Jordan (1990) emphasizing the shortness of the prepatent period of the parasite and its high biotic potential, stated that the number of oocystes produced rises gradually and rapidly attaining high concentration with in short period of time. This supports our observation in that the oocystes count increased sharply from 2nd week and attained the highest concentration at around 6th week.

This study shows that keeping different breeds of birds with different age categories in the same house, a management being practiced in the farm would create a potential risk for establishment of epidemic coccidiosis. This is because different breeds have different rates and period of faecal oocystes excretion thus contributing to the difference in the level of contamination of the environment by viable oocystes. This can be particularly potential source of infection for new batch of chicken where in the farm prior and subsequent removal of litter and disinfection of the house is only occasionally practiced and feeding and watering troughs cleaned and changed. Such kind of management would assist the establishment of resistant and viable oocystes that can be readily transported in live birds, which some times remain carriers for long period of time and become sources of infection for others. It was, thus, recommended that rearing chickens of different age groups, widely separated from each other, plays a pivotal role in the prevention of transmission of coccidiosis.

Furthermore, in this study increasing resistance to coccidiosis was shown to be possible through genetic selection and that keeping local chickens can help reduce incidence of the infection, provided that appropriate management is practiced.

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Antibiotic Sensitivity of Mastitis Causing Bacteria Isolated From Dairy Cows in Welayta Soddo, Southern Ethiopia

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Abstract

In Welayta Soddo, mastitis is a highly prevalent disease of economic as well as public health importance and antibiotic therapy is the principal method of controlling the disease. Antibiotic sensitivity test using disc diffusion method was conducted on 43 strains of bacteria isolated from clinical and subclinical mastitis cows of local zebu and Jersey breeds in Welayta Soddo, southern Ethiopia. Tested organisms include *Staph. aureus*, *Staph.epidermidis*, *Streptococci* species, *Coryn. Pyogenes*, *Esch.coli*, *Coryn.bovis* and *Kleb. aurogenes.* The results indicated that the organisms showed varying degrees of sensitivity to antimicrobial agents tested. Of the total organism tested, 67% exhibited resistance to Penicillin, 58% to Polymyxin, 56% to Streptomycin and 35% to Trimethoprim. Almost all the population of *Staph. aureus*, the most frequently isolated pathogen, were resistant to 80% of the drugs tested where as only 24% of the population of *Staph. epidermidis*, were resistant to 80% of the antibiotics tested. Similarly, 26% of *Streptococci* species showed varying degrees of resistance to seven types of antibiotics. Penicillin exhibited poor activity against 87%, 45% and 40% of *Staph.aureus*, *Staph.epidermidis* and *Streptococci* species population respectively and to the whole population of the rest isolates. Likewise, streptomycin exhibited poor activity against 60% and 64% of *Staphylococci* and *Streptococci* species population, respectively. On the other hand, Gentamycin and Chloramphenicol were demonstrated to be the most active antibiotics (98% and 95% of the organisms exhibited sensitivity to theses antibiotics). Mishandling and irrational use of the drugs over a long time had led to the emergence of resistant bacterial population. Thus, proper handling and application of antibiotics together with routine drug sensitivity test and appropriate management and good hygienic

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condition of dairy environment is recommended for better control of mastitis in Welayta-Soddo.

Keywords: Ethiopia/ Welayta-Soddo/ dairy cows/ mastitis/ pathogenic bacteria/ antibiotic

Introduction

Antimicrobial therapy is the primary tool for controlling intramammary infection of dairy cows (Watt, *et al.*, 1995) if properly applied. Antimicrobial drugs widely used today are antibiotics which are produced mainly by microorganisms living in the soil where they may play a part in overcoming competing species in their natural habitat (Cruickshank, 1968). In areas where antibiotic therapy is the principal strategy towards the control of mastitis, the nature of interaction between the two vital factors, causal organisms and drugs, over a course of time has to be investigated in order to determine and cope with the problem of drug resistance.

The choice of a drug to be used for treatment of infectious diseases may have to be based not only on a species identification of the causal organisms isolated from the patient but also on the results of in-vitro sensitivity tests made with this particular strain (Cruickshank, 1968). Antimicrobial sensitivity tests provide important information for selecting the most effective antimicrobial agent for use in treatment of intramammary infection (Watt *et al,* 1995). Variations compelling on bacteria an increased resistance to the action of antibiotic drugs are of great importance in medicine because they may lead to failure in the drug therapy of infections (Cruickshank, 1968). Failure of therapy may be due to a variety of factors the most common of which are: incorrect identification of the causative pathogens, the emergence, of a drug-resistant variant of the originally sensitive infecting organisms, and primary infection with a drug- resistant variety of a species of organisms that is generally susceptible to the drug used (Cruickshank, 1968).

Despite an extensive use of different antibiotics separately or in combination for treatment of mastitis in dairy farms in Ethiopia, only very limited information is available on the pattern of sensitivity of mastitis causing microorganisms and the extent of drug resistance problem. And to what extent these factors are affecting the absolute incidence of the disease also remains unclear. Few studies conducted on antibiotic sensitivity of those bacteria causing mastitis (Mengistu, 1986; Geressu, 1989;) revealed the presence of drug resistance problems.

In Welayta, mastitis is a highly prevalent disease and antibiotic therapy, over a long period of time, is the principal method towards control of the disease. However, to what extent this has led to the problem of drug resistance is yet to be investigated. This study, thus, investigates the pattern of antibiotic sensitivity of bacteria responsible for causing mastitis in local zebu and Jersey breeds in Welayta Soddo, southern Ethiopia and recommends the most appropriate drugs that could help control mastitis in the area.

Materials and Methods

Study area

The study was conducted in 1993 in Welayta Soddo, a province located at about 390km south of Addis Ababa. Altitude ranges from 1100-2500 meter above sea level. The area experiences a mean annual temperature of about 19^0C and the rainfall regime over much of the area is typically bimodal with the big rain season occurring from June to September and small rain season from February to April. The annual rainfall ranges from 450 to 1446mm. The prevailing agricultural system is typically mixed farming. Livestock population of the area is estimated to be 1.8 million, of which 53% are cattle, 9% sheep and goat, 3% equines and 35% poultry. Disease is the main constraint of animal production in the area**.** The subsistence needs of increasing human population are causing a progressive expansion of the area under cultivation and subsequent limitation of the grazing lands.

Source of milk samples

Milk samples were collected from local zebu cows managed under traditional husbandry system and Jersey cows from Soddo dairy farm. Zebu cows are milked twice a day and are allowed to dry off by milking at gradually increasing interval. Hygienic milking techniques such as pre-milking and post milking udder washing and disinfecting and routine screening of milk for any abnormality are not practiced. The Jersey cows are managed relatively under good husbandry system. They are kept in exclusive stalls and provided with hay and concentrate and also allowed a grazing time of five hours a day on native pastures. Milking is made by hand twice a day inside the night barns and animals are allowed to dry off at late lactation period by abrupt cessation of milking. Pre-milking udder washing with warm water and drying using clear towel is always practiced although post-milking disinfection is not. Despite the frequent use of several kinds of antibiotics separately or in combination, mastitis remains to be one of the most economically as well as disease of public health importance. Clinical and sub-clinical cases as well as blind quarters are common at any point in time.

Detection of mastitis

Mastitis was detected using bromothymol blue indicator test, strip cup method and physical examination of the mammary glands and milk samples for any abnormalities

Milk sampling

Milk samples were collected from mastitis cows following udder washing using clean and dry towel and disinfected by Benzalkonium chloride (2ml of the reagent was diluted in 1 liter of clean water). Hands were also washed with detergent (soap) and disinfected. The external sphincter of the teats was extruded by pressure to ensure that dirt and wax were removed from the orifices. About 15- 20ml of the milk sample from all affected quarters was collected in sterile test tube in an oblique manner to avoid contamination. During collection, the tubes were canted and well corked to avoid the entrance of dust, skin scales and other contaminants. These were transported to laboratory for detail microbiological analysis. Samples, which weren't processed immediately, were put in refrigerator at 4^0C for subsequent analysis within 12- 24hrs.

Isolation and identification of the organisms

Collected milk samples were analyzed microbiologically at Soddo veterinary diagnostic and research laboratory, department of bacteriology based on the methods described by Brown, *et al* (1969) and David and Peggy (1988) to isolate and identify organisms responsible for causing mastitis.

Antibiotic sensitivity test

Ten antibiotics including those frequently used for treatment of mastitis in the area were tested. These were: Penicillin (10U/IE), Streptomycin (10µg), Tetracycline (30µg), Trimethoprim (75µg), Polymyxin (300/IE), Chloramphenicol (30µg), Kanamicin (30µg), Methicilin (5µg), Gentamycin (30µg) and Cephalotin (30µg). The test involved disc diffusion method described by David and Peggy (1988) and the results compared with zone diameter interpretive standards set for each antibiotic. With a standard concentration of antibiotics in the disc and standard antibiotic sensitivity test media and conditions, the concentration of the diffused antibiotics at any given distance from the disc was relatively predictable and constant (Woolcock and Mutimer, 1983). For each antibiotic minimal inhibitory concentration break points have been established above or below which an organism is classified as resistant (R), susceptible (S) or intermediate (I) sensitivity (David and Peggy, 1988).

Results

The isolates

The following genera of bacteria were isolated and identified in order of importance from microbiologically analyzed milk samples: *Staphylococcus*, *Streptococcus, Corynebacterium* and *Bacillus*. Of the total microorganisms isolated and identified (n=88) from 90 milk samples, 43 strains of isolates (15 S*taph. aureus,* 10 S*taph. epidermidis*, 11 *Streptococcus species* (*Strep.agalactiae*, *Strep. dysagalactiae* and *Strep.uberis*), 3 *Coryn. pyogenes*, 1 *Cory. bovis*, 2 *Esch. coli* and 1 *Kleb. aurogenes*) were tested for sensitivity to ten antibiotics including those frequently used in the area for treatment of mastitis. Selection of the bacteria was based mainly on frequency of isolation. The test was then carried out soon following isolation and identification of the organisms.

Antibiotic sensitivity test pattern

Responses of the organisms to antibiotics tested were summarized in table 2. There were wide ranges of variations in the sensitivity patterns of the isolates to antimicrobial agents tested. From the total isolates showing resistance to the drugs tested, 67% (29), 58% (25), 56% (24), 35% (15), 26% (11), 23%(10) and 19% (8) had shared resistance to Penicillin, Polymyxin, Streptomycin Trimethoprim, Tetracycline, Methicilin and Kanamycin and Chloramphenicol respectively.

Organisms showing multiple drug resistance of considerable concern had also been encountered. *Staph. aureus,* and *Staph. epidermidis*, the first and second most frequently isolated pathogens respectively from clinical and subclinical cases of mastitis in the area, showed resistance to more than three-fourth of the antibiotics tested. 26% of *Streptococcus* species showed resistance to seven types of antibiotics, though in all cases the proportion of resistant bacteria for each drug varied considerably.

Penicillin exhibited poor activity against 87%, 45% and 40% of *Staph. aureus*, *Staph.epidermidis* strains and *Streptococcus* species respectively and to the whole strains of the rest isolates. Similarly, streptomycin demonstrated poor activity against 60% of *Staphylococci* and 64% of S*treptococci species*.

In the present study, Gentamycin was the most active drug against all species of the organisms tested. With the exception of one resistant strain of *Streptococci species*, the overwhelming majorities of the organisms ((98%) were sensitive to the drug. Similarly Chloramphenicol showed good activity against most bacterial population tested (only 5% of the organisms showed resistance against Chloramphenicol). Trimethoprim, Polymyxin and Tetracycline demonstrated poor activity against 60%, 73% and 40%of *Staph.aureus* strains respectively. *Coryn pyogens* showed resistance to seven types of antibiotics namely; Penicillin; Streptomycin, Tetracycline, Trimethoprim, Polymyxin, Chloramphenicol and Kanamicin where as *Coryn. bovis* showed resistance to only Penicillin. Coliform organisms were 100% resistant to Penicillin and 50% resistant to Tetracycline. On the other hand, almost all *coliforms* were sensitive to most antibiotics tested.

Discussion

The relative high incidence of Penicillin and Streptomycin resistant bacterial population (67% and 56% respectively) reported in this study should be of great concern and it consolidates the observation that treatment of mastitis using these drugs is less valuable economically. In fact, Penicillin and Streptomycin, used separately or in combination towards the control of mastitis in Welayta Soddo, were the most common drugs constituting about 85% of the total antibiotics used (Figure.1).

Cruickshank (1968) described that one of the most common causes of failure of drug therapy is the emergence of a drug-resistant variant of the originally sensitive infecting organisms. The presence of many infected cases, with lesions capable of harboring pathogenic organisms subjected to continual treatment with the antibiotics, provides conditions that selectively favor the proliferation and dissemination of virulent strains of bacteria with multiple resistances to antibiotics in common use (Cruickshank, 1968). Mishandling and irrational application of antibiotics towards the control of mastitis (under-dosage, adulteration, inappropriate route and frequency of application, use of expired drugs and mixing with other chemicals) seems to have favored development of drug resistance and hence failure.

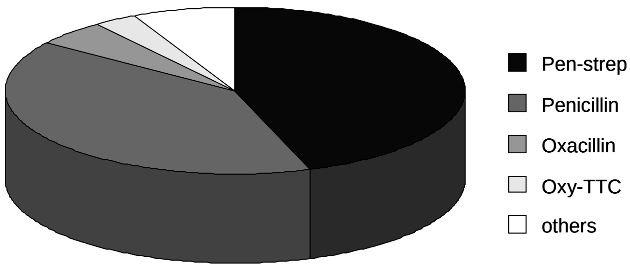

Figure 1. Proportion by percent of antibiotics commonly used for treatment of Mastitis in Welayta

The high incidence of Penicillin-resistant *Staph. aureus* population in this work (86.7%) closely agrees with the findings of Badenhorst (1978) and Mengistu (1986) who reported 83% and 93.3% resistant population of the bacteria respectively. This finding, however, was surprising in relation to the work of Yao and Moellering, (1991) who reported that Penicillin, a β-lactamin antimicrobial agent, is believed to exhibit good activity against Staphylococcus and Streptococcus species. Supporting this opinion, Blood and Radostits (1989) also stated that Penicillin, especially Procaine Penicillin G, is universally used as an intramammary infusion towards the control of mastitis. Brander (1963) also suggested that in order to combat the problem of acquired bacterial drug resistance, synthetic Penicillin should be used among which Oxacillin is the most important one.

However, it was generally reported that drug resistant strains of Staphylococci appeared to be increasing from time to time with varying rate of incidence (Blood and Radostits, 1989). The high degree of Penicillin resistant population of *Staph. aureus* could be attributed to high proportion of strains that are naturally resistant to the drug by virtue of their capacity for producing Penicillinase, an enzyme that destroys Penicillin, or emergence of resistance strains as a result of wide and irrational use of the such drug since their survival and spread is selectively favored (Cruickshank, 1968). On the other hand, the high degree of Penicillin and Streptomycin resistance of these organisms could be explained from the fact that a drug sensitive pathogens is present in a part of the body, in which drug-resistance commensal bacteria may be present, thus it could acquire a drug- resistance character by the transfer of genes from one of the later organisms (Cruickshank, 1968). In this work too *Staph. epidermidis* and Streptococci species showed considerable resistance to Penicillin (40% and 45% resistance respectively).

The findings of the present study revealed that Gentamycin and Chloramphenicol were found to be the most active and recommendable drugs in the treatment of mastitis. Rao *et al* (1989) and Chandra (1988) also reported that Gentamycin and Chloramphenicol were the most effective antibiotics against mastitis pathogens. Fred (1960) observed the importance of Chloramphenicol in the treatment of many staphylococcal infections that were resistant to Penicillin, Streptomycin and Tetracycline. However, the use of such drugs in the area is limited because of unaffordable cost and inadequate supply.

As little was known about the incidence of drug resistant population of mastitis causing bacteria, the findings of the present study could be of considerable value in formulating mastitis treatment strategies in Welayta Soddo. Mishandling and irrational use of antibiotics had, interalia, contributed much to the development of drug resistance problem particularly with those antibiotics commonly applied for treatment of mastitis.

In this study Penicillin and Streptomycin were shown to be ineffective drugs against the treatment of mastitis while Gentamycin and Chloramphenicol were the best. Because of the complexity of the disease they cause and their opportunistic nature and high capacity to develop adaptation with changing environment mastitis causing bacteria are widely spread and persistently present in dairy environment. Thus, control of mastitis by chemotherapy along seems less feasible unless integrated with factors like appropriate management and good hygienic condition of the dairy environment. However, proper handling and rational use of antibiotics is very important in areas where drug therapy is the principal method of controlling the disease. Furthermore, the application of routine drug sensitivity test is recommended as this technique assists not only proper selection of the drugs to be used but also reveals the extent of resistance problem in the area.

Table 1. Responses of the test organisms to various antibiotics

Test organism	No. Tested	Sensitivity of test organisms to antibiotics																													
		Penicillin (10U/IE)			**Methicillin (5µg)**			**Streptomycin (10µg)**			**Gentamycin (10µg)**			**Tetracycline (30µg)**			**Trimethoprim (75µg)**			**Polymyxin (300/IE)**			**Cephalotin (30µg)**			**Chloramphenicol (30µg)**			**Kanamycin (30µg)**		
		S	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**	**S**	**I**	**R**
Staph.aureus	15	2	-	13	12	-	3	3		9	15	-	-	9	-	6	6	-	9	4	-	11	10	-	5	15	-	-	10	-	5
Staph. epidermidis	10	6	-	4	7	-	3	4	-	6	10	-	-	9	-	1	8	-	2	7	-	3	7	-	3	10	-	-	8	-	2
Strep.species [a]	11	4	2	5	9	-	2	4	-	7	10	-	1	10	-	1	9	-	2	3	-	8	11	-	-	11	-	-	11	-	-
Coryn.pyogens	3	0	-	3	3	-	-	2	-	1	3	-	-	2	-	1	1	-	2	0	-	3	3	-	0	2	-	1	2	-	1
Coryn.bovis	1	0	-	1	1	-	-	1	-	-	1	-		1	-	-	1	-		-	1	-	1	-	-	1	-		1	-	-
Esc.coli	2	0	-	2	0	-	2	2		-	2	-	-	1	-	1	2	-	-	2	-	-	2	-	-	2	-				-
Kleb. aurogen	1	0	-	1	1	-	-	0	-	1	1	-	-	0	-	1	1	-	-	1	-	-	1	-	-	-	-	1	1	-	-
Total	**43**	**12**	**2**	**29**	**33**	**-**	**10**	**16**	**3**	**24**	**42**	**-**	**1**	**32**	**-**	**11**	**28**	**-**	**15**	**17**	**1**	**25**	**35**	**-**	**8**	**41**	**-**	**2**	**35**	**-**	**8**

[a] Streptococci species tested include Strep. agalactiae, Strep. dysagalactiae, Strep.uberis.

Responses of the bacteria to antibiotics were expressed as resistance (R), sensitive (S) or Intermediate (I).

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Information for Contributors

General

Ethiopia is one of the countries endowed with a large number and diverse livestock resources. The spectacular land formation, ranging from mountain chains with peaks of over 4500 m asl to areas below sea level, has created diverse climatic conditions with variable agro-ecological zones and rich biodiversity. This unique variability has afforded the country for the evolution and development of different agricultural production systems. Different species and breeds of livestock have been domesticated and used for various purposes. The different production systems and the economic and social roles that livestock play in the livelihood of millions of smallholder farmers is substantial. The proper exploitation of this large number and diverse livestock resource in the country has remained a great challenge to all professionals engaged in livestock production. This has also afforded a number of national and international organizations a great opportunity to undertake research and development activities to ensure proper utilisation and conservation of these resources.

In order to co-ordinate such efforts and to streamline the research and development agenda, The Ethiopian Society of Animal Production (ESAP) has been operational since its establishment in 1985. ESAP has created opportunities for professionals and associates to present and discuss research results and other relevant issues on livestock. Currently, ESAP has a large number of memberships from research, academia, and the development sector. So far, ESAP has successfully organised about 10 annual conferences and the proceedings have been published. The ESAP Newsletter also provides opportunities to communicate recent developments and advancements in livestock production, news, views and feature articles. The General Assembly of the Ethiopian Society of Animal Production (ESAP), on it's 7th Annual Conference on May 14, 1999, has resolved that an Ethiopian Journal of Animal Production (EJAP) be established. The Journal is intended to be the official organ of ESAP.

The ***Ethiopian Journal of Animal Production (EJAP)*** welcomes reports of original research data or methodology concerning all aspects of animal science. Study areas include genetics and breeding, feed resources and nutrition, animal health, farmstead structure, shelter and environment, production (growth, reproduction, lactation, etc), products (meat, milk, eggs, etc), livestock economics, livestock production and natural resources management. In addition the journal publishes short communications, critical review articles, feature articles, technical notes and correspondence as deemed necessary.

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To serve as an official organ of the Ethiopian Society of Animal Production (ESAP).

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Table 1. The following are examples of SI units for use in *EJAP*

Quantity	Application	Unit	Symbol or expression of unit
Absorption	Balance trials	Grams per day	g d^{-1}
Activity	Enzyme	Micromoles per minute per gram	µmol min^{-1} g^{-1}
Area	Land	Hectare	ha
	Carcass	Square centimetre	cm^2
Backfat	Carcass	Millimetres	Mm
Concentration	Diet	Percent	%
		Gram per kilogram	g kg^{-1}
		International unites per kilogram	IU kg^{-1}
	Blood	Milligram per 100 mL	Mg dL^{-1}
		Milliequivalents per litre	Mequiv L^{-1}
Density	Feeds	Kilogram per hectolitre	Kg hL^{-1}
Flow	Digesta	Grams per day	g d^{-1}
	Blood	Milligrams per minute	mg min^{-1}
Growth rate	Animal	Kilogram per day	Kg d^{-1}
		Grams per day	g d^{-1}
Intake	Animal	Kilograms per day	Kg d^{-1}
		Grams per day	g d^{-1}
		Grams per day per kg $bodyweight^{0.75}$	g d^{-1} $kg^{-0.75}$
Metabolic rate	Animal	Megajoules per day	MJ d^{-1}
		Watts per kg bodyweight	W kg^{-1}
Pressure	Atmosphere	Kilopascal	KPa
Temperature	Animal	Kelvin or degree Celsius	K or ^{o}C
Volume	Solutions	Litre	L
		Millilitre	ML
Yield	Milk production	Litres per day	L d^{-1}
Radioactivity	Metabolism	Curie or Becquerel	Ci (=37 GBq)

Units with two divisors should be written with negative indices (e.g., kg ha^{-1} yr^{-1}). The use of solidus (/) should be reserved for units written in full (e.g., mole/kilogram) or to separate a physical quantity and unit (e.g., yield/ha). Units should be chosen so that the numeric component falls between 1 and 10 or 1 and 100 when using one or two significant figures, respectively (e.g., use 31.2 mg than 0.0312 g).

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