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Environmental Factors Affecting Milk Production in the Holstein-Friesian Population of Zimbabwe

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Abstract: The milk production of a cow is a result of the interaction of both genetic and environmental factors. Lactation records for calvings from 1979 to 1998, from Zimbabwe Dairy services Association were used to estimate the effects of the non-genetic effects on milk production. The model fitted had the fixed effects of herd, season of calving, parity and days in milk. Herd effects were significant (< 0.001). The effect of herd was found to be ranging from 14 to 47% of the total variation in the records. The contribution of the herd on fat and protein percent was lower compared to the contribution to yield traits. Month of calving had a significant effect on milk, fat and protein yield (<0.0001), but had no effect on fat percent and protein percent. The highest yields were in the months of May to August. The Temperature Humidity Index (THI) ranged from 55.95 to 67.78, which is within the range for breed in under study. It had no effect on protein percent. Milk production increased up to parity 5. Protein percent increased from parity one to parity two and then remained almost constant. Fat percent declined from parity one. Milk production and component production increased with increasing days in milk. However, days in milk had no significant effect on fat percent and protein percent. The effect of days dry, days open and calving interval were not studied as they were serious confounding effects which made it impossible to estimate the effects of each one of them. The results indicate that outside economic constraints Zimbabwe can produce milk without the need for strong environmental modifications.

Key words: Non-genetic factors, temperature humidity index, herd, season, days in milk, parity

INTRODUCTION

The current software that are used to estimate random effects including breeding values of animals also simultaneously estimate the fixed, environmental effects using the mixed model methodology. These are based on the Best Linear Unbiased Prediction (BLUP). The Best Linear Unbiased Estimates (BLUE) are linear combinations of b(t'b) which is a linear combination of the observations. These fixed effects are then used to estimate the random effects, which include the breeding values of all the individual animals in the population under study. The breeding values are random because each individual in the population gets a random sample of the genes from the parents. The genetic parameters are predicted after adjusting for the non-genetic factors. This is important because for accuracy in selection, it is crucial that the records reflect as precisely as possible the cow genetic potential for milk production. The actual records themselves may be poor indicators of the breeding values because many environmental factors have a marked influence on a cow's performance during a particular lactation. There are many factors that have to be considered which are non-genetic that affect milk production. These include herd, parity, age at calving, length of the lactation period, number of times milked per day, length of the preceding dry period, days open, season (month) of calving, calving interval and year of birth. It has been well documented in Zimbabwe that regions have an effect on milk production[1]. Chauhan[2] partitioned herd, year and season variance in an analysis of milk production and found that the herd effect accounted for 30% of the total variance in milk and fat yield. Milk production decreases with increasing heat stress particularly for high producing dairy cows. Heat stress being any combination of environmental

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parameters producing conditions that are higher than the temperature range of the animals' thermal neutral zone[3]. The dairy cows from the temperate regions are more sensitive. These factors have to be included in the mixed model analysis as fixed effects so that they do not introduce bias to the genetic comparisons. BLUP removes the need for pre-knowledge of the value of each one of the fixed effects, which in reality, in most populations are not known.

This study seeks to quantify the effects of the different non-genetic factors that were estimable. The work on non-genetic factors affecting milk production may reveal the need to have matings and hence calvings that occur at certain times of the year that give higher yields with less extra input. It also indicates the optimal levels of those factors that could be used below or above which productivity may be reduced. This may mean moving away from the year round calvings to calvings concentrated in certain months. Certain levels of the non-genetic factors result in losses. Quantifying these losses is very important so as to convince the farmers to avoid those levels of those environmental factors. It may also indicate the management interventions that can be used to optimize production. This study presents the effects of those non-genetic factors that can be quantified.

MATERIALS AND METHODS

The environment: Zimbabwe is located in Southern Africa in the tropical savannah region. The total land area is 390,759 square kilometres. About 7.25% is arable, 0.25% is under permanent crops like coffee, 12.5% is grass veld and 49% are forests and woodlands. A central plateau lying between 1200 and 1500 m above sea level dominates Zimbabwe's landscape. The climate is subtropical moderated by altitude. The rainy season is November to March with a dry cool season from May to August. The rainfall increases from less than 450 mm in the southwest to more than 1200 mm in the northeast[4]. The mean annual temperature range is 16 to 25°C[4]. Anderson *et al.*[5] describe a more detailed description of agro-ecological zones of Zimbabwe. The dairy farms are located within 40 km of the major towns and cities.

The records: The milk production records were obtained from the Zimbabwe Dairy Services Association (ZDSA). Kunaka[6] described the dataset and the edits. This gave a dataset of 30,379 records. This was then split into three datasets EVNH73, ODNH73 and ALL87 for reasons given by Kunaka[6]. Initial analysis using the General Linear Model (GLM) procedures of the Statistical Analysis Systems[7] were done to determine the non-genetic factors that affected the milk production traits in the population. The fixed effects of previous calving interval, days dry, days open and age at calving were excluded. This was due to the fact that days open are not recorded at ZDSA. Also it is highly correlated to the calving interval. Age at calving confounded with parity and these two are highly correlated. Days dry confounded with calving interval and parity. This confounding was evident from the initial General Linear Model analysis of SAS, where the degrees of freedom were not what they were expected if these were included. Makuza and McDaniel[8] reported that the fixed effects, which included calving interval, days open, days dry among others were not estimable from parity 3 on wards when the authors were working on the data set from ZDSA for the period from 1973 to 1987. Interactions among these fixed effects would result in them being nonestimable. Times milked per day was not examined because ZDSA had incomplete records. The traits examined were milk yield, fat yield, fat percent, protein yield and protein percent. The animal model used had the fixed effects of herd, month of calving, year of birth for datasets EVNH73 and ODDNH73, the dataset ALL87 had these fixed effects plus the effects of parity, linear and quadratic functions of days in milk. The month of calving define the season of calving. The Temperature Humidity index for each month were calculated from the data obtained from the Meteorological Department in Harare and averaged. The breeding values for each animal were estimated using AIREML of Gilmour *et al.*[9] that was also used to estimate the variance components and the genetic parameters. The effect of the environmental factors was taken as the BLUE of the AIREML solutions. The temperature humidity index for each month was calculated using the formula after Johnson[10]. The formula is:

$$THI = DBT + DPT \times 0.36 + 41.2$$

Where:

THI is the temperature humidity index;
DBT is dry bulb temperature;
DPT is the dew point temperature.

The figures for the DBT and DPT were averages over the twenty years for the major dairy areas of Zimbabwe.

RESULTS AND DISCUSSION

Effects of year of birth: There were significant differences between years of birth (<0.0001). The year effects contributed 0.52 to 17. 20% of the variation in the traits studied. The different years have differences in rainfall amount and distribution. Therefore years have different effective rainfall. These differences also result in years having different disease challenges and feed resources. Year of birth must therefore be included in the model for genetic analysis involving more than one herd over a long period.

Effects of herd: Herd was found to significantly (<0.0001) affect milk yield, fat and protein yield and fat and protein percentage of Holstein dairy cattle in Zimbabwe (<0.0001). The effects of herd have been reported in Zimbabwe[1,11,12] and in other countries[2,13,14]. It is expected that different herds have different levels of production because of variations in the level of management. In herds where disease control is high and feeding regime is also high, production is expected to be high. In Zimbabwe herds are found in different agro-ecological zones, which could explain part of the differences between herds[1]. The type of farming activities on the farm contributes to the variation among herds as some of the by-products from other activities can be used as feed ingredients for dairy cows where these are available. The values shown in Table 1 range from 14 to 47% and agree with literature values, ranging from 25 to 47% for milk and FCM[1]. The variation attributed to herd for fat and protein percent is much lower compared to their yields possibly because these are affected by many other factors.

Most of the variation in milk and milk components between herds of the same breed is apparently due to differences in the level of nutrition and management and likewise this is the case with regard to changes in herd averages from year to year. The effects of nutrition and management are part of herd effects. The changes may be temporary or may follow a certain trend. Milk production requires that a cows maintenance requirement and part of the milk production be provided from roughage. In Zimbabwe, this is easily done in summer from veld grazing until mid-January when the feeding value of the grass begins to decline. The cows are fed concentrates for milk production above 5 kg/day. In winter, when the quality of the veld is poor the cows are given maize silage, or grass hay for maintenance. Different systems are used in different herds to offer the concentrates to the cows. One such system is the conventional feeding system, in which a cow is given concentrates according to amount of milk being produced per day. The second system is the budget feeding system. A fixed amount of concentrates is offered each day based on expected daily milk yield for each cow and offered for the whole year. The concentrates are offered at 0.44 kg kg^{-1} of milk produced. The last system involves the calculation of the peak yield. Cows are then fed on a flat rate for the first 20 weeks so that nutrient intake in this period is the same as it would have been with conventional feeding system. From week 21 on wards, the amount of concentrates offered is calculated for each subsequent six weeks period. The concentrate allowance is then offered in equal quantities reducing in four steps[15]. The general management of cows in Zimbabwe is as outlined in the Dairy Farmers' handbook[16].

Table 1: The contribution of herd to the total variation in the various traits

Data	Trait	Contribution (%)
EVNH73	Milk yield (kg)	46
n=46	Fat-corrected-milk (kg)	46
	Fat (kg)	44
	Fat (%)	31
ODNH73	Milk yield (kg)	46
n=47	Fat-corrected-milk (kg)	41
	Fat (kg)	35
	Fat (%)	33
ALL87	Milk yield (kg)	25
n=49	Fat-corrected-milk (kg)	24
	Fat kg)	22
	Protein (kg)	21
	Fat (%)	14
	Protein (%)	15

A number of environmental factors influence the yield of contemporary cows causing deviations from the true production ability of the individuals. Some of these factors are possible to control e.g., variations in feeding or in the milking interval but others evade management control. Management in Zimbabwe like in other tropical environments faces the problems of insufficient and costly feed supplies, disease and parasitic challenges and narrow margins between input costs and output prices[17]. These limitations have hindered the growth of the dairy industry in Zimbabwe.

Effects of month of calving: Month of calving had a significant effect on milk, fat and protein yields (<0.0001). Neiva *et al.*[18] reported that month of calving had no effect on milk and fat yield and fat percent, in the Brazilian Holsteins. Generally the peaks were from May to August for all yield traits. This could be due to the lower ambient temperatures[19-21] and low THI during these months (Table 2). Lowest yields were in the hot months of February and between October and December. This

Table 2: The average THI for the 12 months of the year in Zimbabwe

Months	THI	Milk yield	Fat yield	Protein yield
1	67.78	000.0000	0.0000	00.0000
2	67.49	-002.655	-0.2805	03.258
3	66.51	085.44	2.0445	08.044
4	63.68	208.84	6.966	12.80
5	59.98	280.85	9.294	14.30
6	56.67	283.75	8.416	14.56
7	55.95	266.1	6.350	12.91
8	58.74	183.1	3.641	10.34
9	62.62	129.95	2.658	07.939
10	64.88	55.83	0.2198	07.281
11	66.70	03.015	-1.056	06.643
12	67.36	00.4835	-1.132	04.758

agrees with the earlier findings[1,11,22]. This is because milk production decreases with increasing heat load[23,24]. The reason for this is that the lactating cow partitions the energy ingested into energy available for the various uses in order to meet the requirements for certain functions and down to the energy converted into milk[25]. The efficiency of energy and other nutrient metabolism has not been influenced by selection for milk yield. The heat load from environment has to be within certain limits of THI of between 35 to 72 for the Holstein cows[10] otherwise the nutrients are channelled to the maintenance of the body temperature (homeotherm). Table 2 show that none of the months' THI fell outside the range for the breed under study. However, month of calving had no effect on fat percent and protein percent in all the three data sets. It means that these are under the influence other factors.

Effects of parity: Milk yield and fat yield increased up to parity 5 (Fig. 1 and 2) and decreased in EVNH73 data set (Fig. 3). However, in ODNH73 data set there was a gradual increase up to parity 6 and then a big increase to parity 7. This difference could be due to sampling. There was a steady decline in fat percent from parity 1 in all the three data sets. This could be due to negative genetic correlation between fat percent and milk yield[26]. In general, milk, fat and protein yield peak productions were attained in parity four m for the ALL87 data set (Fig. 4). Protein percent increased to parity 2 and then remained at that level (Fig. 5). The decline in fat percent was expected as fat percent has a negative correlation with milk yield[27]. Generally, the capacity of milk yield increase at a decreasing rate until body maturity is reached. Production maintains a plateau for several years and then begins to decline beyond 12 years of age. The production ability is not only influenced by the body development but also by the development of the udder (mammary size) and hormonal stimuli with recurrent pregnancies and lactations. The former accounts for 20 to 60% and the later accounts for 40 to 80% of the increases[28]. Reduced efficiency of utilisation of nutrients and the general metabolism of the cows after senescence starts, result in declining production. The cows reduce hormonal secretions when they reach 12 years[28].

Effects of days in milk: The linear and quadratic effects of days in milk were significant for milk yield, fat yield and protein yield (<0.001). However, the linear and quadratic effects were insignificant for fat and protein percent implying that other factors not studied affect these traits. This agrees with the finding of Musani and Mayer[29]. There is a lot of variation in days in milk in the ZDSA records. Yet, there are no correction factors for days in milk for the Zimbabwean Holstein population at present.

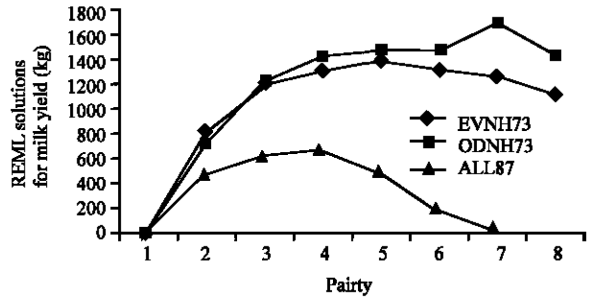

Fig. 1: Effect of parity on milk yield in all three data sets

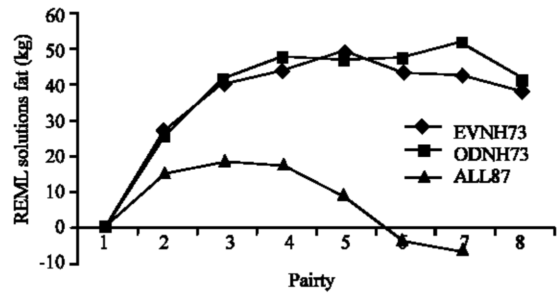

Fig. 2: Effect of parity on fat kg in the three data sets

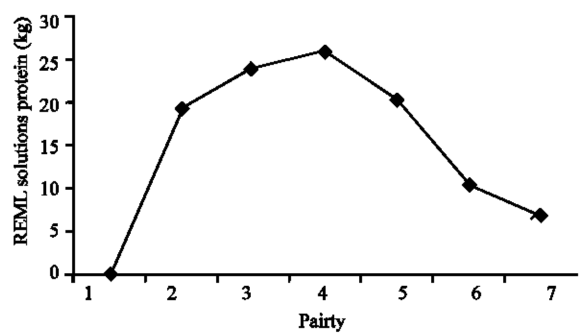

Fig. 3: Effect of parity on protein kg in the ALL87 data sets(1987-1994)

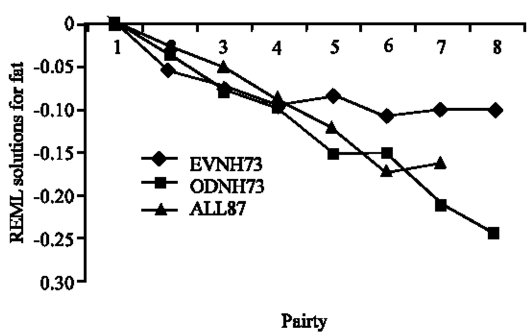

Fig. 4: Effect of parity on fat % in the three data sets

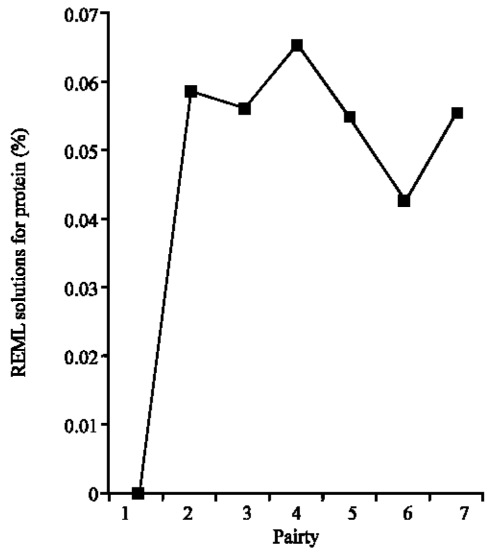

Fig. 5: Effect of parity on protein 5 in ALL data set (1987-1994)

These correction factors need to be developed rather than depend on the Canadian correction factors, as is the case now. These Canadian factors may not be appropriate as reported by Muchenje *et al.*[30].

Herd, month of calving, parity, linear and quadratic effects of days in milk and the quadratic effect of days in milk significantly affected milk yield, fat yield and protein yield. There was no variation in fat percent and protein percent with month of calving. May to August gave highest yields in all the three data sets. The lowest yields were in February and between October and December. Peak production occurred at parity four in fat-corrected-milk, milk yield, fat yield and protein yield. Fat percent decreased with parity whilst protein percent increased to parity 2 and stayed unchanged.

The months from May through to August gave the highest milk production and from a production point of view, these are the best months to produce milk especially for those farmers who want to have seasonal calving in their herds.

Milk yield, fat yield and protein yield increased up to parity four. Therefore farmers should keep cows to parity 4 to 7. There is need to use a selection index, which has these in it in order to have improvements in fat percent and protein percent rather than just increase the carrier. There is no environmental limitation to milk production in Zimbabwe. Therefore the milk producers' objective must be to produce as much milk as possible within the limits of their resources under the prevailing economic conditions.

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