Scientific Journal of Animal Science (2013) 2(5) 102-108
ISSN 2322-1704

Contents lists available at Sjournals

Scientific Journal of Animal Science

Journal homepage: www.Sjournals.com

Original article

Non-genetic factors affecting milk yield and composition of Holstein-Friesian cows nested within natural ecological regions of Zimbabwe

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A R T I C L E I N F O

Article history:
Received 27 February 2013
Accepted 08 March 2013
Available online 28 May 2013

Keywords:
Natural ecological region
Year of calving
Milk yield
Milk composition

A B S T R A C T

Milk production is affected by genetic and non-genetic factors. Knowledge of these factors is essential for efficient management and accurate estimation of breeding values. The objective of this study was to establish and analyze non-genetic factors which affect milk production and composition in Holstein-Friesian cows. A total of 4 500 milk records from the Zimbabwe Dairy Services Agency (ZDSA) from 1999 to 2004, were used. Natural ecological region, month of calving and year of calving had significant (P<0.05) effect on milk yield, protein and fat composition. Therefore, correction for environmental effects is necessary to increase accuracy of direct selection for milk yield and composition.

1. Introduction

In Zimbabwe, the population of the dairy herd has been on a progressive decline over the past 30 years. The present dairy industry has around 24 000-27 000 (Dairibord Zimbabwe, 2012; International Dairy Federation, 2012) dairy cattle compared to 81 672 dairy cattle as of 1999 (Central Statistics Office, 2003) and a peak of 122 000 in 1989 (Mupunga and Dube, 1994). The herd decline has been attributed to several factors including management aspects (Ngongoni *et al.,* 2006), increased costs of production and poor adaptability of the exotic breeds to the local production environment. The Holstein-Friesian breed is the major dairy breed in Zimbabwe constituting about 80%of the dairy herd (Central Statistics Office, 2003) hence much research should be conducted to improve its productivity under local environmental conditions. It is the highest yielding dairy breed as compared to other dairy breeds although it produces low butterfat content compared to the Jersey breed. Originally a temperate breed, it is of high economic importance in the country because of its high milk production. Pure breeds average 6 000 to 7 000 litres of milk per lactation (Makuza, *et al.,* 1999). Butterfat in Holstein-Friesian cows varies from 2.5% to 4.3% with the average of the breed being 3.6% fat (Kunaka, 1998). The same authors reported that the butterfat constitutes 28.5% of the total solids in the Holstein-Friesian breed. First parity, is at 28 to 32 months and thereafter once in 12 to 13 months. Genetic and non-genetic factors influence milk production potential. Milk production efficiency usually increases when productivity increases (Muchenje, 1996), a function of the two factors. Therefore it is necessary to have corrections or adjustments for these factors when analysing for performance verifications. Non-genetic factors in milk production are those effects that are not part of the genetic makeup of an animal (Makuza *et al.*, 1999). These include parity, calving interval, days in milk, age at first calving, days dry, month of calving, year of calving and nutritional status of the cow. If understood these factors can be manipulated to maximize productivity (Amimo *et al.*, 2007). Therefore, there is need for periodical accurate genetic evaluation and selection criteria of the breeding herd. For the smallholder farmers to succeed in dairy production there is need to provide effective technical support to reduce cost. It is therefore critical to provide information on both the genetic and non genetic factors that influence milk production. A study on the non-genetic-factors affecting milk production in Holstein-Friesian cows is therefore justifiable. The results can be used as a management tool, to improve selection criteria by accounting for non-genetic factors. The objective of this study was to determine the effect of non genetic factors on milk yield, protein and fat content.

2. Materials and methods

2.1. Environment

Zimbabwe is located in Southern Africa in the tropical savannah region. The total land is 390,759 km^2 and it is divided into five agro ecological regions. Rainfall patterns and crop production progressively deteriorate from ecological regions 1 to 5. However, livestock production including dairying is practiced in all the ecological regions (Gambiza and Nyama, 2000). In the regions with low rainfall, dairying is assisted by production of drought-resistant fodder crops (Chinogaramombe *et al.,* 2008; Jingura, 2000). Most dairy farms are located within 40 km of the major cities and towns (United States Department of Agriculture (USDA), 2009).

2.2. Data and data edits

The standard 305-day milk production records of pure bred Holstein-Friesien were obtained from Zimbabwe Livestock Identification Trust. Eight commercial farms were selected using stratified random sampling and natural ecological regions 1, 2a, 2b, 3 and 4 were considered. Each natural region was represented by two commercial farms. Nyamushamba (2006) described the data set and the edits. This gave a data set of 4 512 records with cows calving in the period 1999-2004 respectively. Animals were grouped by year of birth born from 1997 to 2002. Records were of individual cow milk yield, butterfat and protein contents.

2.3. Statistical analysis

The data was analysed using an animal model of the General Linear Model (GLM) of Henderson Type III sum of squares in Statistical Analysis Systems version 9.1.3 (SAS, 2004). All duplicate records were deleted to remove bias from the data. The data was fitted to the following animal model;

$$Y_{ijk} = \mu + NR_i + F_{(i)j} + E_{ijk}$$

Where

- Y_{ijk} is the observations on TMY, % Protein and % Fat associated with k^{th} animal under j^{th} factor level nested within i^{th} Natural Region;
- K in 1-n animals
- i is Natural Region
- j is the factor level
- μ is the overall mean of j^{th} sampling population;
- NR_i is the effect due to Natural Region (i = 1; 2a; 2b;3; 4)

$F_{(i)j}$ is the effect of j^{th} factor level with j nested within i^{th} Natural Region;
E_{ijk} is random residual error associated with k^{th} observation

3. Results

Figures 1, 2, and 3 show the effect of natural ecology on butter fat, protein content and milk yield respectively. The Butter Fat content obtained in natural region 2b and 3 were not significantly different (P>0.05). There was no significance difference (P>0.05) between the BF content of natural region 4 and 1. However, the Butter Fat content in natural regions 3 and 4 were significantly different (P<0.05) from each other. Protein content in natural region 3 was significantly (P<0.05) different from natural region 4 whereas natural region 2a and 2b were not significantly (P>0.05) different. There was a significant difference (P<0.05) between the total milk yield recorded in natural region 1 and natural region 4 whilst natural region 2b and 4 were not significantly different (P>0.05).

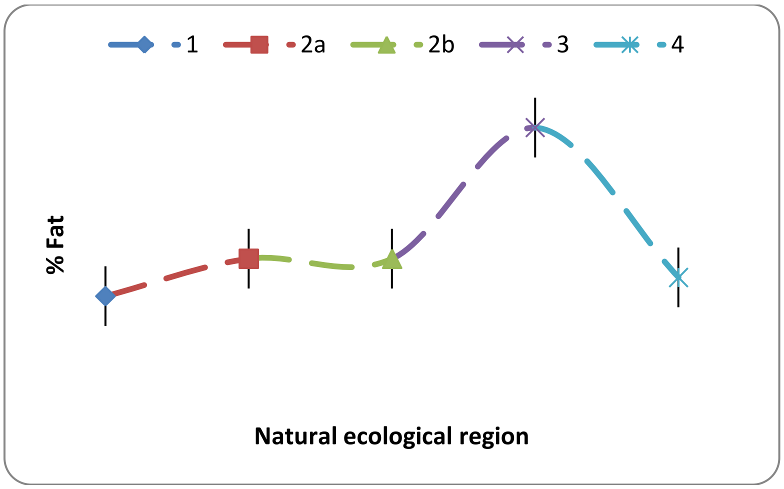

Fig. 1. Effect of natural ecologicl region on % butter fat.

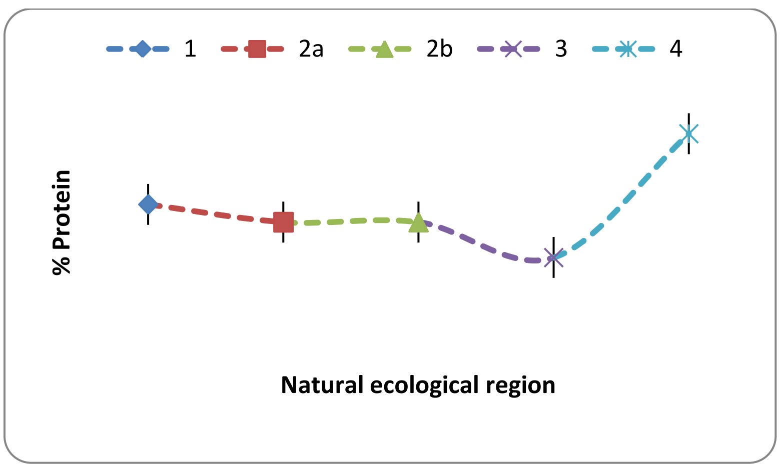

Fig. 2. Effect of natural ecological region on % protein content.

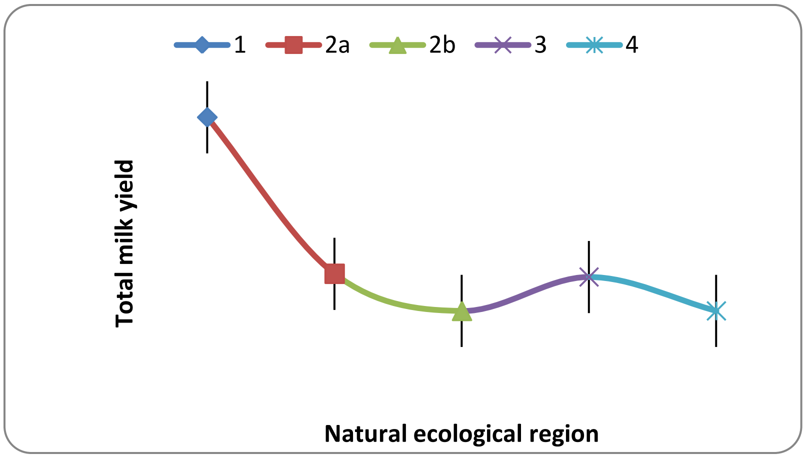

Fig. 3. Effect of natural ecological region on total milk yield.

Table 1
Effect of year of calving on butter fat, protein and total milk yield.

YOC	%Fat	% Protein	Total milk yield
1999	1.93^{b}	1.77^{b}	5987^{a}
2000	1.89^{d}	1.76^{bc}	6275^{a}
2001	1.90^{cd}	1.74^{cd}	5933^{a}
2002	1.93^{b}	1.73^{d}	6233^{a}
2003	1.93^{b}	1.77^{b}	5787^{a}
2004	1.98^{a}	1.79^{a}	6144^{a}
±SEM	**0.02**	**0.02**	**541**

Means in the same column with the same superscript are not significantly different (P>0.05).

Table 1 show the effect of year of calving on butter fat, protein content and milk yield. The level of fat in 1999 (1.93%) was significantly (P>0.05) different from 2004 (1.98%). The butterfat content in 1999 (1.93%), 2002 (1.93%) and 2003 (1.93%) were not significantly different (P>0.05). Means of protein levels recorded in 1999 (1.77%) and 2000 (1.76%) were not significantly different (P>0.05) whereas those of 2002 (1.73%) were significantly different (P<0.05) from 2004 (1.79%). Means of total milk yield recorded from 1999 to 2004 were not significantly different (P>0.05).

Table 2
Effect of year of calving nested within a natural region on butter fat.

Year of Calving	**Natural ecological region**				
	1	**2a**	**2b**	**3**	**4**
1999	1.87^{b}	1.93^{a}	1.88^{a}	1.98^{a}	1.96^{a}
2000	1.91^{b}	1.89^{a}	1.91^{a}	1.85^{a}	1.94^{a}
2001	1.91^{b}	1.86^{b}	1.87^{a}	1.94^{a}	1.96^{a}
2002	2.05^{a}	1.70^{c}	1.88^{a}	2.10^{a}	1.40^{b}
2003	1.89^{b}	1.91^{a}	1.90^{a}	2.07^{a}	1.40^{b}
2004	1.89^{b}	1.91^{a}	1.95^{a}	2.35^{a}	1.44^{b}
±SEM	**0.04**	**0.05**	**0.09**	**0.56**	**0.06**

Means in the same column with the same superscript are not significantly different (P>0.05).

The level of butterfat content recorded in 1999, 2000, 2002, 2003 and 2004 were significantly different (P<0.05) from that recorded in 2001 of natural region 1 (Table 2). In natural region 2a, the level of fat recorded in the year 2002 was significantly different (P<0.05) from all the other values. In natural region 2b and 3 there was no significance difference among all the fat levels as from 1999 to 2004. In natural region 4, levels of fat recorded in 2003 and 2004 were significantly different (P<0.05%) from the other fat levels recorded as from 1999 to 2002. In natural region 1 and 2a, levels of protein recorded as from 1999 to 2004 were not significantly different (P>0.05) (Table 3). In natural region 2b, protein values recorded from 1999 to 2001 were significantly different (P<0.05) from those recorded as from 2002 to 2004. In natural region 3, levels of protein recorded from 1999 to 2000 were significantly different (P<0.05) from other protein values recorded in other different years. In natural region 4 protein levels recorded as from 2000 to 2002 were significantly different (P<0.05).

Table 3
Effect of year of calving nested within a natural region on protein content.

Year of Calving	Natural Ecological Region				
	1	**2a**	**2b**	**3**	**4**
1999	1.75^{b}	1.79^{a}	1.76^{a}	1.75^{ab}	1.77^{b}
2000	1.75^{b}	1.76^{a}	1.76^{a}	1.78^{a}	1.74^{bc}
2001	1.75^{b}	1.72^{b}	1.75^{ab}	1.71^{bc}	1.74^{bc}
2002	1.76^{b}	1.76^{ab}	1.74^{ab}	1.67^{c}	1.71^{c}
2003	1.79^{a}	1.75^{b}	1.74^{ab}	1.74^{ab}	1.81^{ab}
2004	1.81^{a}	1.78^{a}	1.73^{b}	1.72^{b}	1.84^{a}
±SEM	**0. 02**	**0.03**	**0.02**	**0.04**	**0.03**

Means in the same column with the same superscript are not significantly different (P>0.05).

Table 4
Effect of year of calving nested within a natural region on total milk yield.

Year of Calving	Natural Ecological Region				
	1	**2a**	**2b**	**3**	**4**
1999	9537^{a}	5977^{a}	4201^{b}	5440^{b}	4482^{c}
2000	9410^{a}	5487^{b}	5080^{a}	8225^{a}	3175^{cd}
2001	10431^{a}	5428^{bc}	5156^{a}	6025^{b}	2873^{d}
2002	10823^{a}	4964^{c}	3744^{c}	4367^{c}	7267^{b}
2003	9558^{a}	4920^{c}	3309^{c}	2985^{d}	8464^{b}
2004	10744^{a}	4664^{c}	2356^{d}	3034^{d}	9984^{a}
±SEM	**1030**	**491**	**857**	**1 000**	**1310**

Means in the same column with the same superscript are not significantly different (P>0.05).

In natural region 1, levels of total milk yield recorded as from 1999 to 2004 were not significantly different (P>0.05) (Table 4). The values of the total milk yield were 9537, 9410, 10431, 10823, 9558 and 10744 respectively. In natural region 2a, the level of total milk yield recorded in 1999 was significantly different (P<0.05) from all other values. Levels of total milk yield recorded in 1999, 2002 and 2003 of the natural region 2b were not significantly different (P>0.05). In natural region 3, the total milk yield recorded in the year 2000 was significantly different (P<0.05) from all other values recorded in other different years. In natural region 4, levels of total milk yield recorded from 2002 to 2004 were significantly different (P<0.05) from those recorded from 2000 to 2001.

4. Discussion

The observations that natural region, year of calving and month of calving were significant sources of variation on butterfat, protein and total milk yield agree with literature (Mangwiro, 1998). The authors reported that, if calving occurs during the dry year the milk yield and quality is adversely affected. The low milk yield recorded from 1999 to 2003 is therefore a result of scarcity of livestock feeds. Costs of commercially produced feeds for example concentrates were very high and this contributed to low milk production (Ngongoni *et al.,* 2007).

According to Fontaneli *et al.* (1998) differences in performance between years reflect effects of environmental variations, which have marked effects on the quantity and quality of herbage available. Gambiza and Nyama (2001) have reported such differences in Zimbabwe. The changes in milk production as a result of the month of calving can be attributed to the changes in nutrition associated with the time of the year. Holstein-Friesian cows that calved during a drought year produce less milk than the cows that calve years when rainfall is in abundance due to the positive correlation between veld pasture and rainfall amount. Differences between years are a normal phenomenon which is caused by unforeseen fluctuations in environmental conditions that are difficult to control. The month within a year in which they calved is very important. Milk quantity and quality is a function of the feeding conditions (Mpofu, 2004). As feed quality follows a seasonal pattern, Makuza *et al*. (1999) reported that year of calving has a significant effect on milk quantity and quality which also agrees with the findings of Mangwiro *et al*. (1998). The year effect encompasses factors which include feeding management, climate and disease control and management ability of the person responsible for data collection. Milk yield and composition is influenced by nutrition and season (Ngongoni *et al.,* 2006). Year of calving has been found to have a significant influence on milk yield and quality (Erasmus, 1995). Large differences in rainfall lead to marked differences between years in quality and quantity of forage available (Tavirimirwa *et al.,* 2012). Cows in different natural ecological regions produce milk of different quantities and quality in line with environmental conditions characterizing the respective ecological regions.. The observation agrees with literature (Garwe, *et al.,* 2001). Cows calving in a dry environment which are characterized by low rainfall and hence poor quality feed, produce low milk quantities (Mapiye *et al.,* 2006). This was evidenced by cows which calved in natural ecological region 3 and 4. Cows calved in natural region 1 recorded the highest milk yield because of high rainfall and low temperatures, which are optimum for milk production. Low temperatures also reduce stress on animals when they want to feed.

5. Conclusion

Non genetic factors such as natural ecological region, month of calving and year of calving significantly affect milk production dynamics in the Zimbabwe dairy industry. Knowledge of non-genetic factors and the magnitude of their effects are therefore essential in milk production. It is also important to note that the effect of natural ecological region should be considered first before adjusting for any other factor. Focus should be on developing animal models which suit the local environment rather than base on European based animal models since local environmental conditions are different to conditions characterizing Europe.

Acknowledgement

The authors are grateful to the Zimbabwe Dairy Services Agency for providing data used in the study and Mr N Mware for technical assistance.

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