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EFFECTS OF ENVIRONMENT ON PRODUCTIVE PERFORMANCE OF HOLSTEIN-FRIESIAN DAIRY COWS IN THREE AGRO-ECOLOGICAL REGIONS OF ZIMBABWE

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Abstract: The level of performance in any livestock production enterprise is a function of genetic and non-genetic factors and their interaction. For the purpose of agricultural production decisions, Zimbabwe was divided into five agro-ecological zones (AEZ) according to rainfall intensity, distribution and length of rainy season. Commercial dairy production, based on specialist dairy breeds such as Holstein, Holstein-Friesian and Jersey, is confined to AEZ I, II, III and IV. The performance of these breeds in contrasting AEZ has not been determined. In this study, farm level data of 7562 Holstein-Friesian cows calving in the period 2003-2011 was used to compare milk yield and milk components across three contrasting AEZ of Zimbabwe. A Generalized Linear Model (GLM) was fitted to investigate the fixed effects of year, season and AEZ and random effects of days in milk (DIM) on milk production and component traits. The factors herd, agro-ecological zone, year and season had significant (P<0.001) effects on all variables tested. The most favourable performance of Holstein-Friesian cows was observed in AEZ II and during the hot-dry season due to higher test-day milk yield, protein, butterfat and total solids, and lower somatic cell counts. However, season and agro-ecological region are not limiting factors for commercial dairy production in Zimbabwe. Where animal performance may be sub-optimal, opportunities do exist for using strategies and technologies that help adapt and cope with climate conditions.

Keywords: Non-genetic factors, Agro-ecological zone, Dairy cattle, Herd, Season

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1. Introduction

Productivity of dairy cattle is determined by interplay between genetic and non-genetic factors and their interactions. Non-genetic factors affecting milk production include herd, year, season, parity, and days in milk, among others. Awareness of non-genetic effects and expected levels of production for particular breeds in specific environments may inform breed choice for those environments and production systems (Valencia et al., 2007). For the scientist, it presents an understanding of whether genetic or environmental factors are the most efficient avenues through which productivity can be improved in specific environments (Hammami et al., 2009). For farmers, knowledge of environmental effects on performance of animals can significantly increase efficiency of genetic improvement programs.

Historically, the Zimbabwe dairy industry has been dual in nature, comprising large scale commercial farms and smallholder multi-enterprise farms that varied with scale of production (Chirinda et al., 2021), Zvinorova et al. (2013) observed that several dairy farming systems co-exist in the country, being shaped by agro-ecological diversity, differences in human settlement patterns and population density, land tenure, resource endowments, and the resultant economic opportunities available for farmers. Consequently, Gororo (2016) proposed a new dairy classification model where farms are demarcated by dairy herd size and defined in terms of business objectives, production levels, labour organization, feeding systems, resource endowments, use of technology and marketing. In that classification scheme, dairy farms are categorized by scale into subsistence (< five dairy animals), small scale (family farms, 5-10 dairy animals); intermediate or medium scale (modest investment in dairy, 10-100 dairy animals); and large scale (corporate or family farms, >100 dairy animals). Medium to large scale dairy operations dominate the industry, producing 95-97% of all formally marketed milk in the country (Chirinda et al., 2021). These farms are more mechanized, capitalized and employ semi-skilled and skilled labour for all year-round milk production using planted pastures, maize silage, forages and concentrates as feed resources. This diversity means that every farming system is unique, facing distinctive production and marketing challenges and opportunities and recommendation domains for sustainable dairy development for each sector also need to be unique.

Since the mid-1990s, Zimbabwe's dairy production has been declining and the demand-supply gap for milk and milk products in the country has been widening. Milk yield declined from 262 million liters in 1990 to <37 million liters in 2009 followed by a steady but slow increase to 82 million liters in 2021 (Chirinda et al., 2021). Viability and competitiveness challenges, and agrarian reforms led to farm closures, down-sizes, stagnation and shortage of new entrants. Starting in 2017, the country and industry implemented the Dairy Revitalization Program, a multi-pronged approach designed to build local production capacity and reduce the demand-supply gap. The objective of the Dairy Revitalization Program is to increase the national dairy herd and increase farm yields through access to better genetics and breeds for local farmers. Specialist dairy heifers and cows were thus directly imported into the country to replace or complement local non-dairy breeds and dairy cross breeds that predominated small scale dairy farms (Chirinda et al., 2021). The program focused on the importation and distribution of specialist dairy heifers of the Holstein-Friesian breed, as well as small numbers of Jerseys, on diverse farm systems and agro-ecological zones. The Holstein-Friesian was preferred for its higher milk yield potential. However, the breed requires high levels of management, being susceptible to sub-optimal nutrition; parasites, disease and heat stress (Nyamushamba et al., 2012). Jersey and Red Dane breeds on the other hand are reported to be more adaptable and resilient to local production conditions.

For the DRP, there is a challenge of choice of production system- and farmers to target as beneficiaries for imported specialist dairy heifers. Early studies in Holstein-Friesian dairy cows in Zimbabwe focused on milk production potential and the genetic and non-genetic factors influencing milk production, composition and hygienic quality (Missanjo et al., 2010). However, the effect of environment on Holstein-Friesian cows has never been reported in dairy scientific research in Zimbabwe. Awareness of environmental effects and expected levels of production for Holstein-Friesian breed in specific environments may inform breed choice for those environments and production systems. The present study was therefore carried out to assess the effect of agro-ecological zone on the performance of Holstein-Friesian dairy cows in Zimbabwe. The aim was to generate research-based evidence for recommendation domains to use on where and in which system the Holstein-Frisian would perform best in Zimbabwe.

2. Material and Methods

2.1. Study Area

Zimbabwe is a subtropical country located in Southern Africa between latitude 19.0154° S and longitude 29.1549° E. The total land size is 390,759 km^2. Zimbabwe's climate is subtropical, moderated by altitude. The country receives uni-modal rainfall, falling during the hot wet season from November to December followed by a warm wet season (January - March). This season is followed by a cold dry season (April - August) and a hot dry season (September - October).

The country is divided into five agro-ecological regions, depending on the total amount of rainfall received, rainfall distribution and length of rainy season. Rainfall patterns, crop yields and pasture production progressively deteriorate from agro-ecological zones (AEZ) regions I to V. These agro-ecological zones were initially delineated in the 1950s by Vincent et al (1960) and reclassified recently by Mugandani et al., (2012). This study was carried out on farms in AEZ II, III and IV where most of the dairy farms are located (Mhlanga et al., 2018; Chirinda et al., 2021). Agro-ecological zone II (AEZ II) is described as intensive crop and livestock farming region. The region receives moderately high rainfall of 750 – 1000 mm/year in at least 18 wet pentads. Rainfall is confined to summer (November to March) with rare but severe mid-season dry spells. Mean annual temperature is 16-19 °C (range: 10-23 °C). Vegetation is dominantly *Hyparrhenia* Tall Grass-veld with a grazing capacity of 2.5-3.5 hectares per livestock unit (ha/LU). Agro-ecological zone III is semi-intensive farming region, reserved for mixed crop-livestock systems. Rainfall is uni-modal (November to March), moderately high (650–800 mm/year), and falls in 14–16 wet pentads. Mean annual temperature range is 18-22 °C. Natural vegetation is mixed-veld dominated by perennial grasses with a grazing capacity of 5-6 ha/LU. Agro-ecological region IV is a lower potential region, receiving fairly low rainfall of 450 – 650 mm/year in less than 14 wet pentads per year. Rainfall is unreliable, variable with periodic seasonal droughts and severe dry spells. The recommended agriculture system is extensive in nature combined with livestock systems based on drought resistant fodder and forage crops. Natural grazing is a combination of the Eragrostis - other species grass veld (7.5-10 ha/LU) as well as Aristida–other species grass veld (10-16 ha/LU). Mean annual temperatures are higher, averaging 18-24 °C.

2.2. Data Collection and Edits

Six commercial dairy farms were selected using stratified random sampling. Only farms practicing intensive dairying, combining grazing, silage and concentrate feeding were considered. From each region, two farms were selected. These farms were on milk recording as part of the Zimbabwe Dairy Herd Improvement (ZDHI) during the period under consideration. Test-day milk production records for 7562 Holstein-Friesian cows calving between 2003 and 2011 were obtained from the

Zimbabwe Dairy Services Agency (ZDSA).

2.3. Statistical Analyses

A complex design of mixed and nesting effects was followed where by the random and fixed factors affecting milk yield and component traits included animal (days in lactation, test day milk yield) and environmental (year, season, agro-ecological zone) factors. There were four seasons: cool dry (April-August), hot-dry (September – October), hot-wet (November - December) and warm-wet (January - March. Test day milk yield (TDMY), milk component traits and somatic cell count (SCC) traits were the response variables. Since herds were only located in specific agro-ecological zones, the factor herd was nested within an agro-ecological zone. SCC data was normalized through log transformation before analyses. Data analysis was done using Generalized Linear Model (GLM) procedure of Minitab 18.1 (Minitab, LLC (2017). Fischer's Least Significant Difference (LSD) was used as the post-hoc test to separate means according to fixed factors, at the 5% significance level. Data was statistically analyzed according to the model given in Equation 1:

$$Y = \mu + Yr + S + F(AEZ) + \beta_1 X_1 + \beta_2 X_2 + e \qquad (1)$$

where;

Y = butterfat, protein, lactose, total solids, TDMY, SCC

μ = overall mean

Yr = fixed effect of the year (2003 to 2011)

S = fixed effect of the season (cold dry, hot dry, hot wet, warm wet)

F(AEZ) = fixed effect of the farm (F) nested within an agro-ecological zone (AEZ)

β_1 and β_2 = regression coefficients relating to covariates

X_1 and X_2 = random effect of covariates (test day milk yield and days in milk)

e = random residual error (which follows a normal distribution).

3. Results

3.1. Effect of the Year

The annual phenotypic trends for TDMY, butterfat, protein, lactose, total solids and SCC are given in Figure 1, 2 and 3. The year of measurement had a significant effect on all variables tested (P<0.001). TDMY showed an upward trend to a peak of 24.0±0.35 kg/d in 2005. This was followed by a decline to a low yield level of 16.0±0.15 kg/d in the year 2008. Thereafter, TDMY started to rise again to a peak of 24.9±0.15 kg/d by 2011. Total solids did not change much across the years. However, there was a downward trend between 2005 and 2009. An initial upward trend to 2005, followed by a downward trend to 2008 and an upward trend thereafter was observed for the parameter, lactose content. Protein and butterfat content started with a downward trend from 3.60±0.036% and 3.90±0.072% in the year 2003. This downward trend ended in 2008 for milk protein (3.18±0.011%) and 2009 for butterfat (3.42±0.063%). Both protein and butterfat content reached a peak in 2010 at 3.67±0.024% and 4.15±0.048%, respectively. SCC showed a general upward trend over the study period and averaged 590x10^3 cells /ml. The level of SCC in milk spiked to 845x10^3 cells/ml in 2005 from a low of 426x10^3 cells/ml in 2004 and started to decline to 478x10^3 cells/ml in 2007. The other years (2008-2011) had higher, but similar levels of SCC.

3.2. Effect of the Season

Seasonal differences were significant (P<0.001) for all variables evaluated (Table 1). Differences in TDMY were small but significant across seasons, with the highest TDMY observed during the hot dry season. This period was also characterised by significantly lower SCC levels and higher lactose and milk protein content relative to other seasons.

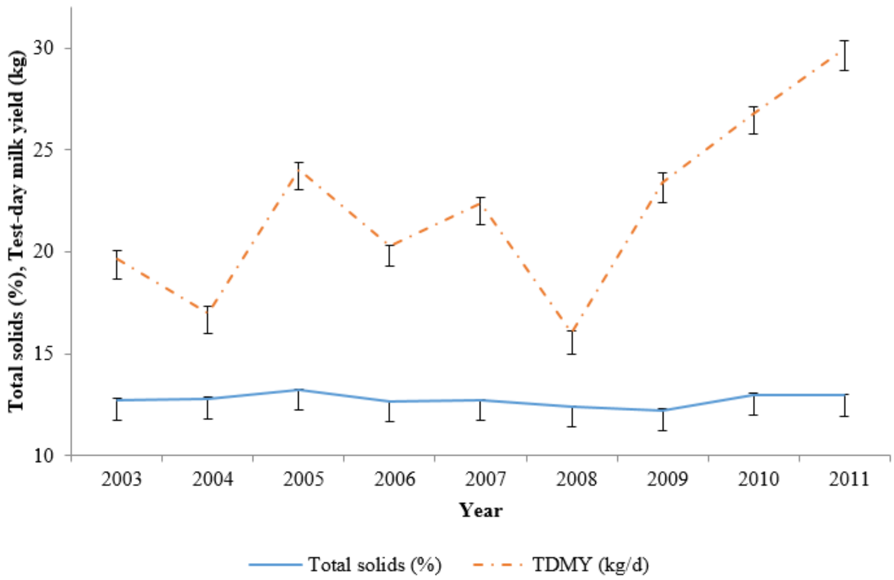

Figure 1. Phenotypic trend of test-day milk yield (TDMY) and Total Solids in Holstein-Friesian cows in Zimbabwe between 2003 and 2011. Error bars indicate SE of mean.

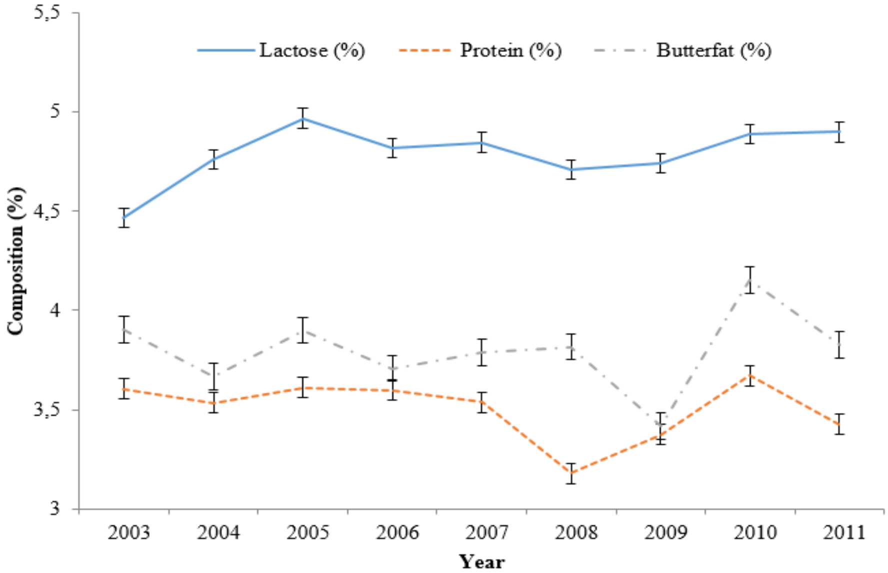

Figure 2. Phenotypic trends for milk components in Holstein-Friesian cows of Zimbabwe between 2003 and 2011. Error bars indicate SE of mean.

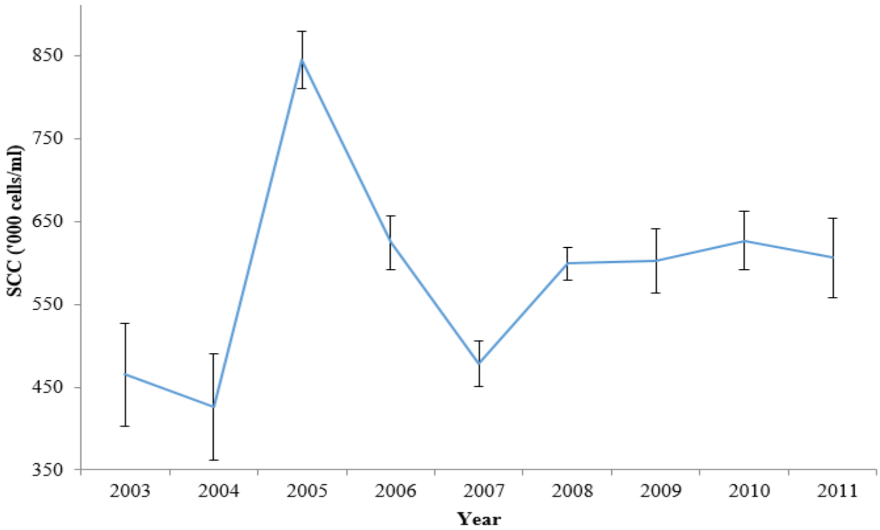

Figure 3. Phenotypic trend for somatic cell counts (SCC) in Holstein-Friesian cows of Zimbabwe between 2003 and 2011. Error bars indicate SE of mean.

The highest SCC was recorded during the cool dry season ($604x10^3$ cells/ml). The hot wet and warm wet seasons did not differ in this parameter (P>0.05). Butterfat content was higher during the warm-wet and cool-dry seasons (3.87%) and did not differ (P>0.05) between these two seasons. Butterfat content was however, lowest during the hot-dry season (3.67%). Lactose content was significantly higher during the dry seasons compared to the wet seasons. The four seasons differed (P<0.001) in total milk solids with the warm-wet season having the highest (12.92±0.033) and hot wet season having the lowest (12.56±0.033) value for this parameter.

3.3. Effect of the Agro-Ecological Zone

Agro-ecological zone had a significant (P<0.001) effect on all milk yield and composition traits analysed (Table 2). Test-day milk yield was significantly higher in AEZ II (26.8 kg/d) compared to AEZ IV (22.1 kg/d) and AEZ III (17.6 kg/d). AEZ II also had significantly higher milk composition traits (butterfat, milk protein, lactose and total solids) relative to other regions. However, no significant difference was observed in butterfat content for farms in AEZ II and those in AEZ IV. The variable SCC was lower in AEZ II (P<0.001), and similar between AEZ III and IV.

3.4. Effect of the Farm Measurement

Within regions, farm differences were observed in some variables (Table 3). In Region II, the two farms differed (P<0.05) in lactose (4.95% vs. 4.92%) and Log-SCC. Farms in Region III significantly differed from each other in protein (3.17% vs. 3.37%), total solids (12.16% vs. 12.43%), SCC (1,022 vs. 152 × 103 cells/ml) and Log-SCC. In Region IV farms differed from each other in butterfat (3.82% vs. 4.11%), lactose (4.66% vs. 4.71%), total solids (12.63% vs. 12.93%), SCC (668 vs. 481 × 103 cells/ml) and Log-SCC.

Table 1. Effect of season (Mean ±SE) on test-day milk yield (TDMY), milk composition and somatic cell counts (SCC) in Holstein-Friesian cows in Zimbabwe

Variable	Season				P-value
	Cold Dry	Hot Dry	Hot Wet	Warm Wet	
TDMY (kg/d)	21.71±20.435[bc]	23.65±20.021[a]	22.03±19.815[b]	21.28±20.077[c]	<0.001
Butterfat (%)	3.87±0.027[a]	3.67±0.029[c]	3.79±0.025[b]	3.87±0.029[a]	<0.001
Protein (%)	3.48±0.013[b]	3.58±0.014[a]	3.40±0.012[c]	3.56±0.012[a]	<0.001
Lactose (%)	4.86±0.009[a]	4.85±0.010[a]	4.71±0.009[b]	4.73±0.009[b]	<0.001
Total Solids (%)	12.82±0.033[b]	12.70±0.038[c]	12.56±0.033[d]	12.92±0.033[a]	<0.001
SCC ('000/ml)	604.4±22.30[a]	495.6±24.70[b]	520.8±21.40[b]	501.0±20.30[b]	<0.001
Log-SCC	2.40±0.018[a]	2.25±0.020[c]	2.35±0.018[b]	2.34±0.017[b]	<0.001

[a,b,c] The same row, means that do not share a letter are significantly different (P<0.001). Seasons were: cold-dry (April-August), hot-dry (September – October), hot-wet (November - December) and warm-wet (January – March). TDMY= test-day milk yield (kg/d)), SCC= somatic cell counts, Log SCC= log somatic cell counts.

Table 2. Least square means (±SE) for effect of agro-ecological zone on milk yield, components and SCC in Holstein-Friesian cows in Zimbabwe.

Variable	AEZ II	AEZ III	AEZ IV
TDMY (kg/d)	26.88±0.159[a]	17.57±0.201[c]	22.05±0.161[b]
Butterfat (%)	3.88±0.041[a]	3.55±0.020[b]	3.96±0.022[a]
Protein (%)	3.76±0.020[a]	3.27±0.009[c]	3.49±0.011[b]
Lactose (%)	4.94±0.014[a]	4.74±0.007[b]	4.68±0.008[c]
Total Solids (%)	13.18±0.053[a]	12.30±0.026[c]	12.78±0.029[b]
SCC ('000/ml)	428.5±34.90[b]	587.7±16.20[a]	575.1±18.30[a]
Log-SCC	2.348±0.0286[b]	2.201±0.0132[c]	2.459±0.0150[a]

[a,b,c] The means in the same row do not share a letter are statistically different (P<0.001), SCC= somatic cell counts, Log SCC= log somatic cell counts, AEZ= agro-ecological zone.

Table 3. Least square means of effect of farm on milk components and SCC

F(AEZ)	TDMY	Butterfat	Protein	Lactose	Total solids	SCC
1(II)	26.88±0.150[a]	3.85±0.043[b]	3.82±0.021[b]	4.95±0.015[c]	13.20±0.056[a]	461.9±36.80[cd]
2(II)	26.66±0.149[a]	3.92±0.048[b]	3.69±0.024[b]	4.93±0.017[a]	13.15±0.063[a]	395.0±41.20[d]
3(III)	17.57±0.200[c]	3.52±0.036[c]	3.17±0.018[e]	4.74±0.012[bc]	12.16±0.047[e]	1,022.9±30.80[a]
4(III)	16.57±0.250[c]	3.57±0.039[c]	3.37±0.019[d]	4.759±0.014[b]	12.43±0.051[d]	152.3±31.50[e]
5(IV)	22.05±0.160[b]	3.82±0.031[b]	3.50±0.015[c]	4.66±0.011[d]	12.63±0.040[c]	668.7±26.20[b]
6(IV)	22.25±0.130[b]	4.11±0.030[a]	3.47±0.015[c]	4.71±0.010[c]	12.93±0.039[b]	481.4±24.60[c]

[a,b,c] The means in the same column do not share a letter are statistically different (P<0.001), F(R)= farm nested within agro-ecological zone, SCC= somatic cell counts.

Table 4. Correlation coefficients of test-day milk yield and days in lactation on milk components and SCC in Holstein-Friesian cows of Zimbabwe between 2003 and 2011*

Variable	Days in Lactation		Test Day Milk Yield	
	r	P-value	r	P-value
Test Day Milk Yield	-0.225	0.000	-	-
Butterfat	0.130	0.000	-0.210	0.000
Protein	0.250	0.000	-0.176	0.000
Lactose	-0.190	0.000	0.420	0.000
Total Solids	0.147	0.000	-0.125	0.000
SCC	0.164	0.000	-0.150	0.000
Log-SCC	0.207	0.000	-0.140	0.000

*All correlation coefficients were significant at P<0.001, SCC= somatic cell counts, Log SCC= log somatic cell counts.

3.4. Effect of Animal on Milk Components and SCC

There was significant correlation (P<0.001) between the animal factors, test-day milk yield and days in lactation with all variables tested (Table 4). Test-day milk yield was found to have a moderate and negative correlation with butterfat (0.210), protein (0.180), total solids (0.130) and SCC (0.150), and a high positive correlation with lactose content (0.42). Significant correlations were also observed for days in lactation with TDMY (-0.225) and lactose (-0.190). Butterfat content, protein, total solids and SCC were moderately and positively correlated to days in lactation.

4. Discussion

Significant fluctuations in test-day milk yield and compositional traits were observed in this study ($P<0.001$). These temporal variations may be related to socio-economic and environmental factors experienced each year (Fontaneli et al., 2005). Kunaka and Makuza (2005) reported that the amount and distribution of rainfall has a positive effect on forage and feed resource availability and disease challenges experienced each year. Serious drought conditions were experienced in the years 2007-2009. In addition, this coincided with the period of economic recession and hyper-inflation, probably reducing the managerial capacity of the farms. This may partly explain lower milk yields and poor compositional quality during the period. These annual fluctuations in milk yield and quality have been reported before for Holstein-Friesian (Nyamushamba et al., 2012) and Jersey cows (Missanjo et al., 2010) in Zimbabwe.

Seasonal differences were observed for test-day milk yield and composition in this study. The year was divided into four seasons and data analysed by season. It was observed that the hot-dry season had the highest test-day milk yield, lactose and milk protein, and the lowest butterfat content. In addition, this was the season with significantly lower SCC relative to the other seasons. A higher milk yield and lower butterfat content observed this season can partly be explained by negative genetic correlation between these two traits. It could also be explained by the absence of green forage, necessary for producing richer, deep yellowish milk.

However, the observation of peak milk yield in the hot-dry season was not expected, since it is the period of forage scarcity and heat stress. Earlier studies (Muchenje et al., 1997; Makuza and McDaniel, 1997; Kunaka and Makuza, 2005) reported peaks for milk yield and compositional traits in the cooler months between May and August. Theoretically, milk production in cows decreases with increasing heat load (Rodriguez et al., 1985). In that case, the cows were expected to partition more and more metabolic energy to homeostasis at the expense of productive functions such as milk production. This study did not interpolate bioclimatic data to check whether heat stress could have been at play. The Temperature Humidity Index (THI) is commonly used to measure the degree at which environmental conditions affect performance of dairy cattle. THI measures the risk of heat stress in dairy cows by combining relative humidity and air temperature. However, Kunaka and Makuza (2005) computed monthly THI for dairy areas using data from the period 1979-1998 and observed that they ranged from 55.95 in the month of July to 67.78 in the hottest month of January. None of these monthly THI values exceeded the limits (~72) for heat load in the Holstein-Friesian breed (Collier et al., 2011). Beyond THI 72, an area is deemed unsuitable for dairy farming as the lactating cow would have to channel significant amounts of metabolic energy to maintenance of body temperature (Mhlanga et al., 2018). Therefore, environmental variations in humidity and temperature may not have had any influence on milk composition and yield. Mhlanga et al. (2018) used three different change scenarios to model and predict future suitability of Zimbabwean landscape for dairy production. Mugandani et al. (2012) reclassified Zimbabwe's agro-ecological zones and found that AEZ II had significantly decreased. These studies show that the naturally suitable areas for dairy are decreasing in extent. Opportunities however exist for using strategies and technologies that help adapt and cope with current and future scenarios (Gwatibaya, 2012; Mhlanga et al., 2018).

Matekenya (2016) posits that better all year-round performance of commercial dairies is partially due to access to extensive grazing areas, conserved forages and financial resources for purchasing supplementary feeds during the dry period. It could be speculated that the higher yields could be related to better management given to the cows during this season as farmers sought to reduce heat stress, maximize production from conserved forages and take advantage of seasonally higher milk prices. Due to availability of conserved forages such as maize silage and hay, season is not a limiting factor for commercial dairy production in Zimbabwe.

Zimbabwe is divided into five agro-ecological regions or zones (AEZ) based mostly on rainfall amount and season quality. When milk yield and composition data for the period 2003-2011 was disaggregated by AEZ, it was observed that AEZ II had the highest milk yield and composition and the lowest SCC. In addition, herd differences were observed for most of the variables investigated. Similar to present findings, Nyamushamba et al. (2012) reported a decrease in lactation yield from AEZ I to AEZ V. In that study, the lowest milk yield was observed in AEZ IIb, whereas AEZ IIa and AEZ III had similar milk yields. Observed regional differences could be related to environmental conditions characterizing each of the respective AEZs.

Herd differences in milk yield and composition are widely reported in Zimbabwe (Makuza and McDaniel, 1997; Kunaka and Makuza, 2005; Nyamushamba et al., 2012). These differences can be ascribed to variations in herd effects of management and nutrition on the various farms. Available feed resources and strategies for delivering them to the farm usually differ from one herd to another. Dairying in Zimbabwe is pasture based with concentrates provided as supplementary feed. During the wet seasons, cows are grazed on natural, planted or reinforced natural pasture up to about March when the grazing starts to lose its feeding value. During the dry non-growing period, roughage is supplied in the form of conserved forage - native or improved grass hay and maize silage. In both seasons, concentrates are given to achieve nutritional requirements for milk production and other physiological needs. Farms differ in their systems of concentrate delivery to the cows, and in the quality and quantity of concentrates and forages delivered. Farms may elect to use conventional (feed to yield), flat rate, budget, lead feeding or combinations of these strategies. General nutritional management of dairy cows in Zimbabwe is detailed in the Dairy Farmers Handbook (Oliver, 1987). Thus, feeding strategy and system are partly responsible for significant variations in performance of farms, even those within the same agro-ecological region. Commercial dairy production involves harvesting and conservation of excess forage during periods of plenty for feeding to cows during periods of scarcity and deficits. Therefore, the non-genetic factors - herd, season and agro-ecological region - may not be serious limiting factors for dairying in Zimbabwe.

In this study, negative correlations were observed between milk yield and milk components, except lactose content, which had a high significant correlation with milk yield. Correlations were in the range of those generally reported in literature, falling between –0.20 and –0.56 (Missanjo et al., 2010; Wongpom et al., 2017). In addition, higher milk yields are associated with less SCC. The negative correlation of milk yield and lactose content with days in lactation is consistent with the standard lactation curve of cows. In early lactation milk yield is rising until it reaches a peak eight weeks post calving and it starts to decline until the cow is dried off. As lactation days advance, milk yield decreases and milk components decrease. SCC was positively correlated to days in lactation. Generally, SCC is higher immediately after calving but drops rapidly during the first week of lactation. The high cell counts the first days of lactation is due to the high immunoglobulin content in the colostrum. It has generally been observed that SCC increases with advancing stage of lactation as drying-off approaches (Hagnestam-Nielsen et al., 2009). For cows with subclinical mastitis, SCC increase significantly towards end of lactation.

5. Conclusion

This study revealed that environment affects performance of Holstein-Friesian cows across contrasting agro-ecological zones of Zimbabwe. It was observed that season and agro-ecological region are not limiting factors for commercial dairy production in Zimbabwe. However, the most favourable performance of cows was observed in AEZ II and during the hot-dry season. It is during these when test-day milk yield and composition traits were higher and SCC lower. AEZ II offers the best conditions for dairy production based on the Holstein-Friesian breed. However, with good fodder and forage planning and management of heat stress, commercial dairy production in Zimbabwe is not limited by season and agro-ecological region.

Author Contributions

O.T. (50%) and T.K.M. (50%) initiated the research, collected data, analyzed and interpreted the data. T.K.M. (50%) and E.G. (50%) wrote the manuscript. E.G. (50%) and O.T. (50%) supervised the research, suggested the research methods, structured the paper and edited the manuscript. All authors reviewed and approved final version of the manuscript.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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