**RESEARCH ARTICLE**

# Do haematological profiles of cows in drought prone areas differ with conformation?

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## Abstract

*Aim of study:* Severe and frequent droughts have resulted in loss of thousands of rangeland cattle worldwide. The objectives of the current study were to assess the reduction in dimensionality of seven conformation traits and to determine the relationships between extracted constructs and haematological parameters associated with drought resilience in beef cows.

*Area of study:* Muzarabani district, Zimbabwe.

*Material and methods:* Fifty multiparous Mashona cows kept on natural rangelands were used. The collinearity of seven conformation traits of the cows was reduced using principal component analysis. The relationships between the principal components and hematological profiles of the cows were subsequently determined using regression analysis.

*Main results:* First extracted principal component described body capacity (body depth, flank circumference, chest girth). The second component described the frame size (stature and body length) of the cows and the third component was comprised of sheath height and dewlap size. Cows characterised by deep bodies, large flanks and chest girths had low percent haematocrit (HCT), mean capsular haemoglobin concentration (MCHC) and red cell distribution (RDW) ($p<0.05$). Small-framed cows were associated with low mean platelet volume (MPV), HCT, MCHC and RDW levels in blood ($p<0.05$). As principal component 3 of conformation traits increased, white blood cell count, mean corpuscular volume, RDW and MPV decreased ($p<0.05$).

*Research highlights:* Small-framed cows with large thoracic capacities, large dewlaps and belly bottoms far away from the ground surface are able to maintain haematological normalcy under rangelands in drought prone areas.

**Additional keywords:** body conformation; haemoconcentration; season; coat colour

**Abbreviations used:** BCS (body condition score); BD (body depth); BL (body length); DL (dewlap size); EOS (eosinophil); FBC (full blood count); FC (flank circumference); HCT (percent haematocrit); HG (heart girth); HGb (haemoglobin); LYMP (lymphocyte count); MCH (mean capsular haemoglobin); MCHC (mean capsular haemoglobin concentration); MCV (mean cell volume); MON (monocytes); MPV (mean platelet volume); NEUT (neutrophils); PCV (packed cell volume); PLT (platelet count); RBC (red blood cell count); RDW (red cell distribution); SH (sheath height); ST (stature); WBC (white blood cell count).

# Introduction

Cattle play important food security and socio-cultural roles in both developed and developing regions (Nyamushamba *et al*., 2017). Most of these cattle, especially in sub-tropical regions, are exposed to harsh production environments that negatively affect their productivity. Droughts are one of the major threats to cattle production in sub-tropical regions (Scasta *et al*., 2015a). Cattle, due to their high maintenance requirements, are vulnerable to water and feed shortage during drought periods (Sejian *et al*., 2016). Owing to frequent and intense droughts, cattle in sub-tropical regions are prone to hydric stress, immunosuppression, nutritional stress and, potentially, death (Dzavo *et al*., 2019).

Some cattle breeds, usually those native to drought stricken regions, have been reported to be resilient and/or resistant to diseases and parasites, hydric stress and nutritional stress (Mwai *et al*., 2015). One such breed is the Mashona breed, a popular beef breed in the sub-Sahara which is native to Zimbabwe. These breeds have, however, been diluted by fast growing genotypes which have been gaining popularity in most communal setups (Zindove *et al*., 2015). Crossing adapted native genes with fast growing genotypes has resulted in nondescript herds with altered adaptability to harsh environmental conditions (Scasta *et al*., 2015a; Dzavo *et al*., 2019). In the wake of frequent droughts and heat waves, it is important to quantify animal-specific drought mitigation strategies. Commonly reported strategies to mitigate drought effects on cattle include sprinkling and shed provision to cool the cattle, supplementation during times of feed shortage and use of borehole water for cattle to drink (Dzavo *et al*., 2019). Genetic selection for drought resilience in cattle has received limited attention (Scasta *et al*., 2015a). The advantage of genetic selection for resilience, in contrast to management improvements, is that it is cumulative and affects all subsequent generations of cattle. There is need to select for improved robustness in cattle herds prone to droughts.

Genetic variation in resilience to drought components such as nutritional and hydric stress has been demonstrated in cattle (Takeda *et al*., 2018; Osei-Amponsah *et al*., 2019) implying that selection for drought resilience in cattle is possible. The genetic architecture underlying resilience to drought in cattle is, however, poorly understood (Osei-Amponsah *et al*., 2019). Use of molecular tools in selection for resilience to drought is, therefore, difficult. Phenotypic selection methods maximize selection gain based on available data. Published estimates of the heritability of feed conversion efficiency in beef cattle ranges from 0.20 to 0.35 (Menezes *et al*., 2018; Takeda *et al*., 2018) whilst those for water intake efficiency as defined by water to weight gain ratio ranges from 0.12 to 0.47 (Menezes *et al*., 2018; Ahlberg *et al*., 2019). The high he-

ritabilities for feed conversion and water intake efficiency indicate that phenotypic selection to improve resilience to nutritional and hydric stress which are proxies of drought resilience in beef cattle is feasible. Optimizing drought resilience in beef cattle, however, still remains one of the most significant challenges of extensive beef producers in drought prone areas (Dzavo *et al*., 2019). This could be due to the fact that drought resilience is a very complex trait consisting of different resilience types. The challenge is to weigh the value of the various measures of drought resilience to pinpoint the most suitable and appropriate measure. It is difficult to define, record and select for all the components of drought resilience. Measurement and recording of the component traits linked to drought resilience is costly, laborious and time consuming (Dzavo *et al*., 2019).

Haematological blood tests are primarily used as indicators of hydric stress, nutritional stress and to detect diseases in cattle (Brucka-Jastrzębska *et al*., 2007). The haematological parameters are, thus, an important tool that helps beef and dairy cattle producers to monitor the health of their cattle. To identify abnormal physiological situations in cattle, values from blood analysis are compared with ranges of standard values (Cozzi *et al*., 2011; Roland *et al*., 2014). Despite the potential usefulness, reference values for haematological values in beef cattle are presented in literature less frequently. A few studies on reference values for haematological values in beef cows used records from open cows (Doornenbal *et al*., 1988). The most popular blood diagnostic test for health status in cattle is the blood count determination, which includes erythrocyte, leukocyte and thrombocyte counts, as well as haemoglobin content, haematocrit value and red blood cell parameters (Singh *et al*., 2013). These parameters are also influenced by hydric and nutritional stress in cattle (Radkowska & Herbut, 2014). Changes in haematological parameters are, thus, possible proxies to predict potential resilience of cattle to hydric, nutritional and pathological stresses in cattle. Drought-resilient cattle are expected to manifest the least changes in haematological parameters when subjected to extreme temperatures, feed shortages and pathological stress (Radkowska & Herbut, 2014). The use of haematological parameters as indictors for drought resilience in cattle is very limited possibly because recording of the haematological parameters requires blood sample collection and analyses which is time-consuming, expensive and labour intensive. Use of conformation traits as indirect indicators of drought resilience in cattle could be an option to improving drought resilience in herds in drought prone regions. There is no data on the relationship between conformation traits with drought resilience as indicated by haematological profiles of cattle.

Conformation traits describe measurements for a range of visual characteristics of an animal and are related

to its anatomical and skeletal appearance (Zindove *et al.*, 2015). There are suggestions that conformation of animals is related to their functional traits such as health, reproduction and survival (Berry *et al.*, 2004; Zindove *et al.*, 2015). In their study on phenotypic and genetic relationships between the conformation traits such as body depth, body length, stature, flank circumference and chest girth and reproductive performance of cattle, Zindove *et al.* (2015) concluded that small-framed cows are more fertile than their large framed counterparts due to adaptability to harsh environmental conditions such as extreme temperatures. Likewise, Forabosco *et al.* (2004) reported that small-framed cows have greater longevity and stability, and are more productive than the large-framed counterparts under continental climates. There is, however, no data on the relationship between conformation traits and adaptability to harsh environmental conditions.

There is need to determine the relationships between conformation traits and haematological profiles before basing selection decisions on conformation with the intention of breeding for improved drought resilience in cattle. Since there are no proper recording programmes yet for haematological profiles and conformation traits, hence a dearth of pedigree information, determination of genetic relationships is difficult. Determining the phenotypic relationships among conformation and haematological profiles can lay the foundation for future exploration of genetic correlations involved. Once the relationship between conformation traits and haematological profiles is established, drought resilient cattle can be bred based on conformation. Using body conformation to select for drought resilience can be very simple and effective. Conformation traits can be recorded and selected for at an early stage and, thus, early selection can be facilitated. Farmers who do not keep records can also indirectly select for drought resilience using conformation traits through visual appraisal.

There is a wide range of conformation traits which can be potentially used in selection for adaptability in cattle and most of the traits are highly correlated (Zindove *et al.*, 2015). Conformations traits of beef cattle have been reported to be strongly correlated with Pearson correlations ranging from 0.5 to 0.81 amongst body depth, stature, chest circumference, body length and flank circumference being reported (Parés-Casanova & Mwaanga, 2013; Zindove *et al.*, 2015). The strong correlations between conformation traits suggest that there is redundancy. Given the collinearity and apparent redundancy between the conformation traits, it is likely that all the conformation traits which are considered during selection of cows do not really measure different constructs. If conformation traits are to be used in selection, there is need to combine them into constructs that describe conformation of the cattle so as to do away with redundancy and collinearity. Identifying dependencies between conformation traits also helps to reduce chances of over- or underestimation of target drought resilience traits during indirect selection using conformation of the cattle. Collinearity of predictor variables can cause wrong identification of relevant predictors and it can be removed using principal component analysis (PCA) (Dormann *et al.*, 2013). After grouping them into principal components, relationship between the conformation traits and indicators of drought resilience can be analysed without redundancy and collinearity. The objectives of the current study were to assess the reduction in redundancy and collinearity of seven conformation traits using PCA and to determine the relationships between extracted principal components and haematological parameters associated with drought resilience in beef cattle.

# Material and methods

Animal handling adhered to guidelines by the Zimbabwe Scientific Animal Act, 1963, subsection 2 of section 4, License Number L624.

## Study site

The study was conducted in Muzarabani district of Mashonaland Central province, Zimbabwe. The district is located at $31^0$ 05' E and $16^0$ 25' S and lies at an altitude of 500 m above sea level (Musiyiwa *et al.*, 2014). The area experiences a semi-arid climate characterized by two distinct seasons; the hot-wet season which occurs from September to April and a cool-dry season during the rest of the year (Katanha & Masocha, 2014). The land surface is largely dry and barren in the cool-dry season. During the hot-wet season, the area is predominated by pasture species unpalatable to domestic livestock. The area is characterised by extremely high temperatures with highest mean monthly maximum temperature of 37 ˚C in February (Mugandani *et al.*, 2012). Rainfall is erratic, averaging 600 mm per annum (Chanza & de Wit, 2014). Frequent droughts are common during the hot-wet season (Musiyiwa *et al.*, 2014). The vegetation type of the area is mainly Mopani bush veld and foothill wooded grasslands (Chanza & de Wit, 2014).

## Sampling and conformation traits measurement

A total of 10 farmers with at least 20 multiparous Mashona cows participated in the study. The farmers were selected using the snow-ball sampling technique (Zindove

& Chimonyo, 2015). The cows were kept on communal natural rangelands. A trained individual measured conformation traits between November 2017 and June 2018. Measurements were taken on dipping days between 1000 h in the morning and 1500 h in the afternoon once in each season; hot-wet season and cool-dry season. A trained individual identified 5 Mashona cows from each of the farmers' herd. The pregnancy status of each cow was then determined by the veterinarian. Only open cows were used for the study. A total of 50 cows from parity 3 to 8 were used. The cows were certified as clinically healthy by a veterinarian. The breed score and body condition score (BCS) of each of the identified cows were then determined. The breed score was determined using a 1 – 9 score based on nine physical characteristics of Mashona cattle (Assan, 2012). The following characteristics were considered: 1: medium frame (stature <170 cm), 2: less developed dewlap and umbilical fold, 3: long tail that almost touches the ground, 4: small rump drooping towards tail, 5: small and prominent eyes, 6: almost non-existent cervico-thoracic hump, 7: small ears with a sharp apex, 8: small udders and teats, 9: short, straight, close and glossy hair. Each cow was given a score corresponding to the number of descriptive characteristics it possessed. For Mashona cattle to be registered with Mashona Cattle Society of Zimbabwe, they should meet at least five of the nine physical characteristics in addition to other minimum performance requirements (Hall, 1998). Assan (2012) reported that Mashona cows that meet at least five of the physical characteristics have the same growth and reproductive characteristics. A cow was, therefore, considered for this study only if it met at least five of the nine characteristics. The five-point European system was used to determine the BCS, where a score of 1 is emaciated and a score of 5 is very fat (Scott, 2017). The cows were held in a cattle crush and restrained in a head bail for measurement and were ear tagged for identification.

Before taking the measurements, each farmer was interviewed on number of calvings of each cow and the coat colour was recorded. The measurements taken are described in Table 1. All conformation measurements were taken using a plastic tape measure. Dentition was used to determine the age of each cow. Cows with visible incisors were categorised as young whilst those with broken or gummy mouth were categorised as old (Raines *et al*., 2008).

## Collection of blood and analyses

Blood samples were collected from the jugular vein on a single day during hot-wet (November 2017) and cool-dry season (June 2018) by a veterinarian. The blood samples were collected in the morning (10:00 h) and afternoon (15:00 h) for each cow. The cows were withheld using a crush pen. Ethylene diamine tetra-acetate (EDTA)-coated vacutainer tubes were used for blood collection. The tubes were stored in cooler boxes with ice blocks and transported to the Diagnopath laboratories, Harare, Zimbabwe, for analyses.

A mindray BC5150 (Shenzhen, P.R. China) automatic cell counter was used to perform full blood count (FBC), lymphocyte count (LYMP), white blood cell count (WBC), red blood cell count (RBC), haemoglobin (HGb) concentration, percent haematocrit (HCT), mean cell volume (MCV), mean capsular haemoglobin (MCH), mean capsular haemoglobin concentration (MCHC), platelet count (PLT), red cell distribution (RDW), mean platelet volume (MPV), neutrophils (NEUT) count, monocytes (MON) count and eosinophil (EOS) count).

Reagents used in the analyses were a diluent, DIFF lyse and LH lyse and probe cleanser. The lysing agent destroys red blood cells and at the same time shrinks the leukocytes cell membrane and cytoplasm for easier determination of the leukocytes. The full blood cell analysis

**Table 1.** Description of the conformation measurements taken on Mashona cows

| Trait | Definition | Reference(s) |
|---|---|---|
| Body depth | Distance between the top of the spine and bottom of barrel at last rib, measured from the left side of the cow | Dubey *et al*. (2012) |
| Body stature | The height of cow hind leg from the ground to the end of the pin bone | BIF (2010) |
| Body length | Distance between the hindmost part of animal to the valley in front of the second thoracic vertebrae just ahead of the centre of the shoulders | Zindove *et al*. (2015) |
| Flank circumference | The linear distance around the body taken just in front of the hook bones, immediately after the udder | Taiwo *et al*. (2010) |
| Heart girth | Total distance around of the animal's heart girth *i.e.* taken just behind the shoulders | Zindove *et al*. (2015) |
| Sheath height | Distance from the ground to the navel | Zindove *et al*. (2015) |
| Dewlap size | The maximum width of skin folds | Khan *et al*. (2018) |

BIF: Beef Improvement Federation

was divided into three main groups (*i.e.*, leukocytes; erythrocytes and thrombocytes). The WBC was measured by the Mindray BC5150 automatic cell counter within 24 h of blood collection. The flow cytometry + tri-angle laser scatter + chemical dye method was done for WBC 5-part differential analysis and WBC counting. In the flow cytometry method used, a fluorescent chemical dye was applied, then the blood films were analysed under a triangle laser scatter beam as described by Furie *et al*. (2011). Peroxidase reagents were used to distinguish between peroxidase-positive cells, such as neutrophils, eosinophil and monocytes.

Erythrocytes that included RBC, HCT and red blood cell indices such as MCV, MCH, MCHC and RDW were analysed through the improved DC impedance method. In the improved DC impedance method, sample tubes containing EDTA anti-coagulated blood were diluted automatically with an isotonic solution prior to analysis. The diluent was forced through an aperture as cells which passed one after the other through the capillary opening. Electrodes on each side of the aperture which had direct current passed through these electrodes. The passing cells would then produce a change in the direct current resistance and thus an electronic signal which is proportionate to its volume. The cells were then identified based on their size and represented in a volume distribution curve, which was defined by the sum of impulses within a certain size distribution. The HCT and packed cell volume (PCV) was determined indirectly from the average size and number of RBCs through the coulter impedance principle as described by Wennecke (2004). The other red blood cell indices (*i.e.*, MCV, MCH, MCHC and RDW) were then automatically determined by the Mindray BC5150 analyser. The refractive index measurements made it possible to distinguish platelets from particles of similar size, thus providing an accurate platelet count (Harris *et al*., 2005).

The HGb was analysed using the Mindray BC5150 machine and the cyanide free reagent method was employed. The principle behind this method as described by Chakravarthy *et al*. (2012) is based on the conversion of all haemoglobin and haemoglobin derivatives, in the presence of a non-ionic detergent, into a stable end product, which shows an absorption maximum at 575 nm. The reaction mixture was then automatically analysed to determine HGb concentration in g/dl.

### Statistical analyses

All data were analysed using SAS (2012). The effect of breed score on conformation traits was determined using PROC GLM. The effects of parity of cow, season, coat colour, age of cow, time of the day and BCS on LYMP, WBC, RBC, HGb, HCT, MCV, MCH, MCHC, PLT, RDW, MPV, NEUT, MON and EOS were determined using PROC GLM for repeated measures assuming fixed models with all possible first-order interactions. First-order autoregressive correlation (AR (1)) was fitted to the model. The model for the final analysis was obtained after eliminating interactions that were not significant ($p > 0.05$).

The PCA was used to organise conformation traits into relatively homogeneous groups called principal components. The matrix of partial correlations, Kaiser Statistic for sampling adequacy was used to determine the degree of interrelations between variables and adequacy for use in principal component analyses. Principal components were chosen based on Kaiser's eigenvalue rule which states than only principal components with eigenvalues greater than one are considered (Cattell, 1966). Principal components were rotated using varimax rotation. The principal components weights of greater than 0.55 were considered to indicate a significant correlation between traits and principal components (Cattell, 1966).

To cater for differences in scales of measurements of the conformation traits, each trait was scored on a scale of 1 to 9, inclusive, according to extremes of the direct measurements for analysis purposes. For example, for body length, a score of 1 meant the cow was among those with the longest bodies and a score of 9 meant the cow was among those with the shortest bodies in the sample. The PROC REG (SAS, 2012) was then used to test whether the relationships between haematological parameters and principal components extracted from conformation traits were linear, quadratic or exponential.

## Results

### Effect of season, time of the day, coat colour and breed score on haematological properties

The effects of breed score on conformation traits in Mashona cows are shown in Table 2. Breed score had no effect on BCS, heart girth, sheath height and dewlap size ($p > 0.05$). Cows with a breed score of 5 were shortest with widest flanks, longest and deepest bodies ($p < 0.05$). Significant levels of parity, season, coat colour, time of the day and body condition score on hematological parameters are shown in Table 3. Season and time of the day had significant effects on WBC, HGb, HCT, MCH, MCHC, MPV, NEUT, LYMP and EOS blood levels. Breed score affected WBC, RBC and HCT whilst BCS affected WBC, RBC, MCV and EOS ($p < 0.05$). Coat colour had significant effect on HGb, MCV and MPV. Season and time of the day had an interaction on HCT, MCV and MCH ($p < 0.05$). Season and coat colour had an interaction on MCH, MON and EOS ($p < 0.05$). The WBC, HGb, HCT, MCH, MCHC, MPV, NUET, LYMP and EOS levels in blood were high during the hot-wet season and during the morning ($p < 0.05$; Table 4). Black

**Table 2.** Effects of breed score on body condition score (BCS), body depth (BD), stature (ST), body length (BL), flank circumference (FC) heart girth (HG), sheath height (SH) and dewlap size (DL) in Mashona cows (n = 200).

| Breed score | BCS | BD (cm) | ST (cm) | BL (cm) | FC (cm) | HG (cm) | SH (cm) | DL (cm) |
|---|---|---|---|---|---|---|---|---|
| 5 | 3.6 ±0.13 | 103.9 ±1.59[a] | 121.4 ±0.51[a] | 137.0 ±2.09[b] | 181.9 ±2.92[c] | 166.2 ±2.32 | 49.79 ±1.58 | 41.1 ±1.18 |
| 6 | 3.5 ±0.14 | 103.9 ±1.73[ab] | 121.9 ±0.73[a] | 138.5 ±2.27[b] | 180.5 ±3.18[bc] | 166.8 ±2.53 | 55.5 ±1.72 | 42.3 ±1.28 |
| 7 | 3.1 ±0.19 | 101.0 ±2.45[ab] | 122.8 ±1.85[a] | 136.3 ±3.21[d] | 171.0 ±4.49[ab] | 160.3 ±3.58 | 50.0 ±2.43 | 37.7 ±1.81 |
| 8 | 3.3 ±0.08 | 100.1 ±0.96[b] | 123.9 ±1.31[a] | 131.3 ±1.26[a] | 171.9 ±1.76[a] | 163.8 ±1.40 | 52.5 ±0.95 | 40.9 ±0.71 |
| 9 | 3.3 ±0.05 | 99.6 ± 0.67[b] | 134.0 ±1.20[b] | 134.6 ±0.88[b] | 171.7 ±1.23[ab] | 163.0 ±0.98 | 52.5 ±0.67 | 41.3 ±0.50 |

Values of in a column with different superscript significantly differ ($p<0.05$)

colored cows had higher HGb, MCV and MPV than their brown counterparts ($p<0.05$). The RBC, MCV and EOS generally decreased as BCS increased ($p<0.05$; Table 4). Variations of MCH, MCV and HCT with day time during the cool-dry and hot-wet season are shown in Fig. 1. During the cool-dry season, MCH, MCV and HCT levels in blood were the same throughout the day ($p>0.05$). During the hot-wet season, cows had high MCH, MCV and HCT levels in blood in the afternoon ($p<0.05$). Seasonal variations in MCH, MON and EOS levels in blood of black and brown cows are shown in Fig. 2. During the cool-dry season, MCH, MCV and HCT levels in blood were the same in back and brown cows ($p>0.05$). Black colored cows had high MCH, MON and EOS levels in their blood during the hot-wet season ($p<0.05$).

## Principal components extracted from conformation traits of Mashona cows

Principal component pattern coefficients of the varimax rotated components and aggregated confirmation trait groups using PCA are shown in Table 5. About 53.79 % of the overall variability of the conformation traits of

**Table 3.** Significant levels for effects of parity, season, coat colour, age, time of the day and body condition score on haematological properties of Mashona cows (n = 200)

| Parameter | Haematological parameters | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WBC | RBC | HGb | HCT | MCV | MCH | MCHC | PLT | RDW | MPV | NEUT | LYMP | MON | EOS |
| Season | ** | ns | ** | ** | ns | ** | ** | ns | ns | ** | ** | ** | * | ** |
| Time | ** | ** | ** | ** | ** | ** | ** | ns | ns | ** | ** | ** | ns | * |
| BS | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| BCS | ns | ** | ns | ns | ** | ns | ns | ns | ns | ns | ns | ns | ns | ** |
| CC | ns | ns | ** | ns | * | ns | ns | ns | ns | ** | ns | ns | ns | ns |
| Parity | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Age | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| Season*Time | ns | ns | ns | ** | ** | ** | ns | ns | ns | ns | ns | ns | ns | ns |
| Season*CC | ns | ns | ns | ns | ns | ** | ns | ns | ns | ns | ns | ns | * | ** |

WBC= white blood cell count; RBC= red blood cell count; HGb= haemoglobin (g/dl); HCT= haematocrit (%); MCV= mean corpuscular volume; MCH= mean corpuscular haemoglobin; MCHC= mean corpuscular haemoglobin concentration (g/dl); PLT= platelet count; RDW= red cell distribution (%); MPV= mean platelet volume; NEUT= neutrophil count; LYMP= lymphocytes count; MON= monocytes count; EOS= eosinophil count and BS= breed score; BCS= body condition score and CC= coat colour. *$p<0.05$; **$p<0.01$; ns: not significant ($p>0.05$)

**Table 4.** Least square means (±SE) of season, time of the day coat colour and age on haematological parameters of Mashona cows (n = 200).

| Parameter | Haematological parameters | | | | | |
|---|---|---|---|---|---|---|
| | WBC | RBC | HGb | HCT | MCV | MCH |
| **Season** | | | | | | |
| Cool-dry | 7.3 ± 0.37[a] | 5.8 ± 0.19 | 8.8 ± 0.27[a] | 28.7 ± 0.77[a] | 49.3 ± 0.86 | 14.6 ± 0.27[a] |
| Hot-wet | 8.7 ± 0.40[b] | 6.1 ± 0.21 | 10 ± 0.29[b] | 31.5 ± 0.84[b] | 49.2 ± 0.94 | 15.5 ± 0.29[b] |
| **Time** | | | | | | |
| Afternoon | 7.6 ± 0.37[a] | 5.7 ± 0.20[a] | 9.0 ± 0.28[a] | 28.8 ± 0.79[a] | 47.6 ± 0.88[a] | 14.6 ± 0.28[a] |
| Morning | 8.4 ± 0.38[b] | 6.2 ± 0.20[b] | 9.8 ± 0.28[b] | 31.3 ± 0.80[b] | 51.0 ± 0.90[b] | 15.5 ± 0.28[b] |
| **Coat colour** | | | | | | |
| Black | 7.8 ± 0.42 | 5.8 ± 0.23 | 9.8 ± 0.31[a] | 30.5 ± 0.90 | 50.3 ±1.00[a] | 15.1 ± 0.31 |
| Brown | 8.2 ± 0.36 | 6.1 ± 0.19 | 9.0 ± 0.27[b] | 29.7 ± 0.76 | 48.3 ± 0.85[b] | 14.9 ± 0.27 |
| **BCS** | | | | | | |
| 4.5 | 7.3 ± 0.45 | 5.6 ± 0.22[bc] | 9.3 ± 0.34 | 29.3 ± 0.92 | 52.3 ± 1.03[a] | 15.8 ± 0.32 |
| 4.0 | 7.9 ± 0.44 | 5.8 ± 0.22[bc] | 9.2 ± 0.33 | 30.5 ± 0.91 | 51.4 ± 1.01[ab] | 15.5 ± 0.32 |
| 3.5 | 7.8 ± 0.35 | 6.3 ± 0.18[a] | 9.0 ± 0.27 | 30.2 ± 0.73 | 48.3 ± 0.81[c] | 14.6 ± 0.25 |
| 3.0 | 8.4 ± 0.39 | 6.2 ± 0.19[ab] | 9.0 ± 0.29 | 29.8 ± 0.80 | 49.7 ± 0.89[bc] | 14.8 ± 0.28 |
| 2.5 | 8.9 ± 1.21 | 5.6 ± 0.16[c] | 9.2 ± 0.91 | 26.4 ± 2.48 | 41.6 ± 2.76[d] | 14.1 ± 0.86 |

WBC= white blood cell count; RBC= red blood cell count; HGb= haemoglobin (g/dl); HCT= haematocrit (%); MCV= mean corpuscular volume; MCH= mean corpuscular haemoglobin; MCHC= mean corpuscular haemoglobin concentration (g/dl); PLT= platelet count; RDW= red cell distribution (%); MPV= mean platelet volume; NEUT= neutrophil count; LYMP= lymphocytes count; MON= monocytes count; EOS= eosinophil count and BS= breed score; BCS= body condition score and CC= coat colour. Values of each parameter in a column with different superscripts differ ($p<0.05$)

the cows concentrated in three extracted principal components. Principal component 1, 2 and 3 accounted for 28.82 %, 14.55 % and 10.42 % of the total variance, respectively. Body depth, flank circumference and chest girth had significant principal component weights in principal component 1 (PC1; principal component weights>0.55). Principal component 2 (PC2) was comprised of stature and body length whilst principal component 3 (PC3) was comprised of sheath height and dewlap size (principal component weights>0.55). Body depth had the highest communality (0.72) and sheath height had the least (0.5).

## Relationships between principal components extracted from conformation traits and hematological parameters of the cows

Relationships between principal components extracted from conformation traits and haematological parameters of the cows are shown in Table 6. The PC1 had negative linear and quadratic relationships with RDW ($p<0.05$). As the PC1 of conformation traits increased HCT, MCHC and RDW decreased quadratically ($p<0.05$). Cows characterised by deep bodies, large flanks and chest girths tended to show low MCHC, HCT and RDW levels in

**Table 4.** Continued

| Parameter | Haematological parameters | | | | | |
|---|---|---|---|---|---|---|
| | MCHC | MPV | NEUT | LYMP | MON | EOS |
| **Season** | | | | | | |
| Cool-dry | 29.8 ± 0.33[a] | 6.4 ± 0.10[a] | 26.8 ± 1.07[a] | 51.4 ± 1.57[a] | 2.26 ± 0.31[a] | 5.22 ± 0.87[a] |
| Hot-wet | 30.7 ± 0.36[b] | 6.7 ± 0.11[b] | 31.8 ± 1.09[b] | 58.1 ± 1.71[b] | 2.98 ± 0.34[b] | 7.39 ± 0.94[b] |
| **Time** | | | | | | |
| Afternoon | 29.7 ± 0.34[a] | 6.3 ± 0.10[a] | 28.1 ±1.03[a] | 52.8 ± 1.61[a] | 2.8 ± 0.32 | 5.7 ± 0.89[a] |
| Morning | 30.9 ± 0.34[b] | 6.8 ± 0.10[b] | 30.4 ± 1.05[b] | 56.7 ± 1.64[b] | 2.8 ± 0.33 | 6.9 ± 0.90[b] |
| **Coat colour** | | | | | | |
| Black | 30.4 ± 0.39 | 6.7 ± 0.12[a] | 29.6 ± 1.17 | 55.1 ± 1.83 | 2.6 ± 0.37 | 6.8 ± 1.01 |
| Brown | 30.1 ± 0.33 | 6.4 ± 0.10[b] | 29.0 ± 0.99 | 54.3 ± 1.55 | 2.7 ± 0.31 | 5.8 ± 0.85 |
| **BCS** | | | | | | |
| 4.5 | 30.1 ± 0.39 | 6.6 ± 0.13 | 31.8 ± 1.25 | 53.6 ±1.93 | 2.8 ± 0.43 | 5.2 ± 1.01[a] |
| 4.0 | 30.1 ± 0.39 | 6.7 ± 0.12 | 29.3 ± 1.24 | 54.7 ±1.90 | 2.4 ± 0.37 | 5.2 ± 1.00[a] |
| 3.5 | 29.8 ± 0.31 | 6.3 ± 0.10 | 29.2± 0.99 | 54.4 ± 1.52 | 1.58 ± 0.30 | 6.5 ± 0.80[a] |
| 3.0 | 30.3 ± 0.34 | 6.4 ± 0.11 | 28.7 ± 1.09 | 53.8 ± 1.69 | 2.3 ± 0.33 | 8.7 ± 0.88[b] |
| 2.5 | 29.5 ± 1.06 | 5.9 ± 0.34 | 27.0 ± 3.38 | 50.8 ± 5.19 | 1.87 ± 0.97 | 8.5 ± 0.72[b] |

WBC= white blood cell count; RBC= red blood cell count; HGb= haemoglobin (g/dl); HCT= haematocrit (%); MCV= mean corpuscular volume; MCH= mean corpuscular haemoglobin; MCHC= mean corpuscular haemoglobin concentration (g/dl); PLT= platelet count; RDW= red cell distribution (%); MPV= mean platelet volume; NEUT= neutrophil count; LYMP= lymphocytes count; MON= monocytes count; EOS= eosinophil count and BS= breed score; BCS= body condition score and CC= coat colour. Values of each parameter in a column with different superscripts differ ($p<0.05$)

blood ($p<0.05$). The PC2 of conformation traits had significant positive linear and quadratic relationships with MPV, HCT, MCHC and RDW levels in blood ($p<0.05$). Small-framed cows were associated with low MPV, HCT, MCHC and RDW levels in blood ($p<0.05$). As PC3 of conformation traits increased, WBC, MCV, RDW and MPV decreased ($p<0.05$).
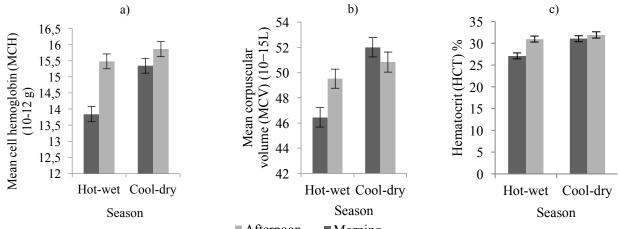
## Discussion

Determination of haematological parameters of cattle is important in establishing their metabolic, health, nutritional and physiological status. The interpretation of haematological parameters hinges on the reference values determined using healthy cattle under similar environmental conditions (Doornenbal *et al*., 1988; Alberghina *et al*., 2011; Cozzi *et al*., 2011). When identifying cattle with hematologic abnormalities, it is important to use reference range generated from a group of healthy cattle with similar physiological characteristics (Roland *et al*., 2014). Published haematological reference values on beef cows used records from open cows (Doornenbal *et al*., 1988) and, thus, to establish an accurate comparison, this study used records on open cows.

**Figure 1.** Mean cell haemoglobin (a), mean corpuscular volume (b) and haematocrit levels (c) in Mashona cows during the morning and afternoon of cool-dry and hot-wet seasons
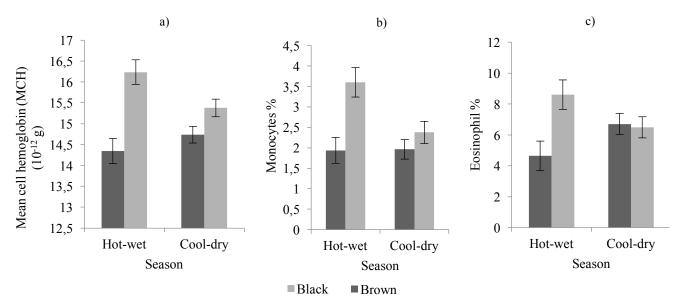


**Figure 2.** Mean cell haemoglobin (a), monocytes (b) and eosinophil levels (c) of black and brown Mashona cows during the cool-dry and hot-wet season

**Table 5.** Eigenvalues and share of total variance and principal component loadings after rotation of conformation traits of Mashona cows during hot-wet and cool-dry season

| Traits | PC1 | PC2 | PC3 | Communality |
|---|---|---|---|---|
| Body depth | 0.89* | 0.21 | -0.16 | 0.85 |
| Stature | 0.16 | 0.67* | 0.08 | 0.48 |
| Body length | 0.32 | 0.61* | 0.31 | 0.57 |
| Flank | 0.90* | 0.08 | -0.09 | 0.83 |
| Heart girth | 0.87* | 0.21 | -0.15 | 0.83 |
| Sheath height | -0.25 | -0.02 | 0.78* | 0.67 |
| Dewlap size | -0.01 | -0.32 | 0.73* | 0.63 |
| Eigen values | 3.26 | 1.12 | 1.00 | |
| Percent of total variance | 28.82 | 14.55 | 10.42 | |

**Table 6.** Regression coefficients (±SE) of principal components (PC) extracted from conformation traits on hematological parameters in Mashona cow cows

| Parameter | PC1 | PC2 | PC3 |
|---|---|---|---|
| Components | BD; FC; HG | BL; ST | SH; DL |
| **Linear** | | | |
| WBC | $-0.04 \pm 0.091^{ns}$ | $-0.1 \pm 0.10^{ns}$ | $0.2 \pm 0.09^{ns}$ |
| RBC | $0.03 \pm 0.030^{ns}$ | $-0.05 \pm 0.05^{ns}$ | $0.08 \pm 0.04^{ns}$ |
| HG | $0.07 \pm 0.069^{ns}$ | $-0.005 \pm 0.074^{ns}$ | $-0.02 \pm 0.011^{ns}$ |
| HCT | $-0.4 \pm 0.19^{ns}$ | $0.05 \pm 0.020^*$ | $-0.1 \pm 0.02^{ns}$ |
| MCV | $-0.3 \pm 0.22^{ns}$ | $0.5 \pm 0.24^{ns}$ | $-0.5 \pm 0.22^*$ |
| MCHC | $-0.2 \pm 0.08^{ns}$ | $0.1 \pm 0.09^*$ | $-0.04 \pm 0.080^{ns}$ |
| PLT | $1.6 \pm 3.29^{ns}$ | $2.3 \pm 3.50^{ns}$ | $-1.4 \pm 3.28^{ns}$ |
| RDW | $-0.2 \pm 0.09^{**}$ | $0.1 \pm 0.09^{ns}$ | $-0.2 \pm 0.09^{**}$ |
| MPV | $-0.03 \pm 0.026^{ns}$ | $0.06 \pm 0.028^*$ | $-0.03 \pm 0.026^*$ |
| NEUT | $0.02 \pm 0.024^{ns}$ | $-0.31 \pm 0.26^{ns}$ | $-0.2 \pm 0.24^{ns}$ |
| LYMP | $-0.2 \pm 0.38^{ns}$ | $0.5 \pm 0.41^{ns}$ | $-0.1 \pm 0.38^{ns}$ |
| MON | $0.03 \pm 0.075^{ns}$ | $-0.1 \pm 0.07^{ns}$ | $-0.01 \pm 0.074^{ns}$ |
| EOS | $-0.4 \pm 0.21^{ns}$ | $0.2 \pm 0.23^{ns}$ | $-0.4 \pm 0.21^{ns}$ |
| | | | |
| **Quadratic** | | | |
| WBC | $-0.004 \pm 0.4837^{ns}$ | $-0.002 \pm 0.0099^{ns}$ | $-0.02 \pm 0.008^{**}$ |
| RBC | $0.003 \pm 0.0049^{ns}$ | $-0.003 \pm 0.0053^{ns}$ | $0.004 \pm 0.0044^{ns}$ |
| HG | $0.009 \pm 0.0070^{ns}$ | $-0.008 \pm 0.0075^{ns}$ | $-0.001 \pm 0.0062^{ns}$ |
| HCT | $-0.04 \pm 0.019^*$ | $0.01 \pm 0.021^{ns}$ | $-0.01 \pm 0.017^{ns}$ |
| MCV | $-0.04 \pm 0.022^{ns}$ | $0.04 \pm 0.024^{ns}$ | $-0.04 \pm 0.020^*$ |
| MCH | $-0.004 \pm 0.0069^{ns}$ | $-0.01 \pm 0.007^{ns}$ | $-0.01 \pm 0.006^{ns}$ |
| MCHC | $-0.02 \pm 0.008^*$ | $0.009 \pm 0.0087^*$ | $-0.004 \pm 0.0072^{ns}$ |
| PLT | $0.3 \pm 0.33^{ns}$ | $0.2 \pm 0.23^{ns}$ | $-0.2 \pm 0.29^{ns}$ |
| RDW | $-0.02 \pm 0.009^*$ | $0.01 \pm 0.010^*$ | $-0.02 \pm 0.008^*$ |
| MPV | $-0.007 \pm 0.0026^{ns}$ | $0.006 \pm 0.0028^*$ | $-0.003 \pm 0.0023^{ns}$ |
| NEUT | $-0.03 \pm 0.025^{ns}$ | $-0.03 \pm 0.027^{ns}$ | $-0.03 \pm 0.022^{ns}$ |
| LYMP | $-0.01 \pm 0.039^{ns}$ | $0.03 \pm 0.042^{ns}$ | $-0.01 \pm 0.034^{ns}$ |
| MON | $0.003 \pm 0.0076^{ns}$ | $-0.009 \pm 0.0082^{ns}$ | $-0.001 \pm 0.0018^{ns}$ |
| EOS | $-0.03 \pm 0.019^{ns}$ | $0.03 \pm 0.022^{ns}$ | $-0.03 \pm 0.019^{ns}$ |

BD = body depth; BS = body stature; BL = body length; FC = flank circumference; HG = heart girth; NH = navel height; DL = dewlap size. $^{**}p<0.01$; $^*p<0.05$; $^{ns}p>0.05$.

Although the WBC, HGb, HCT, MCH, MCHC, MPV, NUET, LYMP and EOS levels in blood were high during the hot-wet season, they dropped back to the range previously reported in cattle under semi-arid conditions (Mazzullo *et al.*, 2014; Roland *et al.*, 2014). Although the period between October and February is classified as the hot-wet season is semi-arid areas, it is now characte-

rised by high temperatures, low rainfall, dry spells and frequent droughts due to climate change over the past decade (Descheemaeker *et al.*, 2018; Dzavo *et al.*, 2019). High WBC, LYMP, EOS and NEUT during the hot-wet season indicate increased immune activity. Heat stress coupled with nutritional and hydric stress during hot and dry periods can result in sick cattle (Broucek *et al.*, 2009;

Ajeet & Meena, 2011; Giri *et al.*, 2017). The same reason can be attributed to high MPV during the hot-wet season. In agreement with our findings, previous studies have reported health problems in cattle exposed to high environmental temperatures, hydric and nutritional stress (Khan *et al.*, 2011; Kamal *et al.*, 2016; Giri *et al.*, 2017). The observation that HGb and HCT levels in blood of the cows were high during the hot-wet season suggests possible haemoconcentration due to reduced plasma volume as a result of reduction of plasma water due to low water intake coupled with increased evaporative cooling (Lamp *et al.*, 2015). The same reasons could explain observed high HCT levels during the afternoon in the hot-wet season. Similary, Obitsu *et al.* (2011) reported an increase in HGb and HCT levels in dairy cows during the hot seasons. High MCH and MCHC levels during the hot-wet season could be attributed to high HGb. High MCH can be due to normal sized cells with high HGb concentrations (Lamp *et al.*, 2015). Higher MCH and MCHC in cattle during the hot-wet season were also reported by Giri *et al.* (2017).

Black cows feel the effects of heat earlier and more than brown and white coloured cows (Atrian & Shahryar, 2012). Black cows are also more vulnerable to hydric stress than their light coloured counterparts because they have high water requirements due to high susceptibility to heat stress (Brown-Brandl, 2018). It can be inferred that black coloured cows had high MCH, MON and EOS during the hot-wet season than their brown coloured counterparts because they were heat stressed and dehydrated. Heat stress and dehydration triggers immune response as indicated by high EOS levels (Giri *et al.*, 2017). The MCH and MON are among the primary indicators of heat and hydric stress in cattle (Pandey *et al.*, 2017). The same reasons could be attributed to high HGb in black cows during the hot-wet season observed herein. Haemo-concentration, resulting in high HGb levels, is more pronounced in dark coloured cattle when environmental temperatures are high (Caulfield *et al.*, 2014). High MCV in black cows during the hot-wet season could be due to increase in cellular oxygen requirements as a result of increased respiration and perspiration (Mazzullo *et al.*, 2014). Increased MCV in black cows during the how-wet season may also indicate vitamin B12 deficiency (Mazzullo *et al.*, 2014). Nutrient deficiencies in cattle under natural rangelands can be exacerbated by thermal stress which reduces feed intake (Nardone *et al.*, 2010). Cows with low BCS had high RBC, MCV and EOS probably because of heat, hydric and/or nutritional stress. Similarly, Mazzullo *et al.* (2014) reported high levels of haematological parameters such as EOS and MCV in thin and emaciated cattle.

Classifying cattle for conformation can be an important tool in cattle breeding and can complement use of records which is expensive, time consuming and labour intensive. Reducing collinearity of conformation traits by grouping them into principal components can reduce

chances of over and/or underestimation of the adaptive potential of the cows during indirect selection. Our findings that three components were extracted tallies with Zindove *et al.* (2015) who extracted two factors describing the conformation of Nguni cows in South Africa. Differences in the number of extracted components could be due to differences in number of variables used. The components of PC1, body depth, flank circumference and chest girth, represents body capacity of the cows (Zindove *et al.*, 2015). In agreement with our inferences, Parés-Casanova & Mwaanga (2013) highlighted that body depth and flank circumference are strong indicators of cattle's rumen capacities. Body stature and body length which were components of PC2 describes the frame size cows (Pundir *et al.*, 2011). Although sheath height and dewlap size were grouped together in PC3, there is dearth of literature describing them as conformation traits in cattle. The two traits are, however, very important adaptation traits in cattle under extreme temperatures and hydric stress (Hansen, 2004; Zindove *et al.*, 2015).

The results of the present study suggest that there is a negative relationship between body capacity of cows and MCHC and RDW values and a positive relationship between frame size of cattle and HCT, MCHC, MPV and RDW. Similar to our findings, the HCT and MPV values of Muturu cattle, a small-framed breed, were reported to be generally lower than Bunaji cattle a large-framed breed in Nigeria (Ode *et al.*, 2017). It is however important to note that, unlike our study, the differences reported by Ode *et al.* (2017) were between breeds. Since both breeds are considered adapted to environmental conditions of the study area (Adebambo, 2001), the differences in the haematological parameters of the two breeds were largely attributed to their morphological differences rather than genetics (Ode *et al.*, 2017). No direct analysis of relationship between haematological profiles and morphology in the subjects was performed and, therefore, it was a tentative explanation of the observed differences. To our knowledge, no similar studies have been performed within cattle breeds. The observed decrease in MCHC and RDW as the body capacities of cows increased and decrease in HCT, MCHC, MPV and RDW as frame size decreased may possibly play a role in the ability of small-framed cattle with large body capacities to strive in stressful conditions such as drought.

The observation that MCHC and RDW decreased as PC1 increased is an indication that cows with large body and rumen capacities are less likely to experience nutritional deficiencies and health problems under stressful conditions such as drought. Scasta *et al.* (2015b) and Zindove *et al.* (2015) argued that large body and rumen capacities helps cattle in drought prone areas to thoroughly digest low quality forage efficiently due to potentially longer passage rates and, thus, meet their nutritional requirements. Deep bodies coupled with large flanks and chest

girths are associated with plenty space for the rumen and digestive system (visceral mass) hence affects the food ingestion, digestion and assimilation capacity of a cow which in turn influences nutritional and health status of the cows (Dubey *et al*., 2012). Cows with small body capacities are more likely to struggle to meet nutritional requirements during times of feed shortages such as drought periods or when grazed on rangelands with pastures of poor nutritional value (Zindove *et al*., 2015). It can, thus, be inferred that cows with deep wide bodies highly suits areas that experience frequent and severe droughts.

Decrease in HCT as cows' bodies, flanks and chests increased in size was unexpected. Large body capacity, as denoted by deep bodies, wide flanks and chests, is associated with plenty space for the rumen and digestive system and this, in turn, affects fermentation rates (Dubey *et al*., 2012). As the body capacity increases the gut capacity also increases and, thus, the cows can consume large amounts of dry matter and fermentation rates are expected to be high (Hansen, 2004). High fermentation rates are associated with increased metabolic heat (Kumar *et al*., 2016). Thus, contrary our findings, cows characterised by deep bodies in addition to large flanks and chest girths are expected to have high HCT since they produce more heat during fermentation which causes haemoconcentration under hot and dry environments (Phillips, 2018). Haemoconcentration results in high HCT levels in blood (Sreedhar *et al*., 2013). The unexpected low HCT in cows with large body capacities could be because of the interactions between chest girth and heat dissipation by the cows. Cattle with large chest girths are able to inhale and exhale large air volumes thereby losing much heat to the environment through the vapour released in the breath (Brown-Brandl, 2018). This implies that low HCT in cows with large flanks and chests might be due to better ability to disperse heat and not due to reduced heat production.

The positive relationship between PC2 (body length and stature) and HCT, MCHC, MPV and RDW maybe a reflection on the interactions between nutritional status, health status and frame size in cattle kept under drought prone areas. High HCT, MCHC, MPV and RDW levels in cattle are an indication of nutritional and health problems such as iron-deficiency anaemia, immune mediated thrombocytopenia and haemo-concentration (Roland *et al*., 2014). As PC2 increased, hence frame size, HCT, MCHC, MPV and RDW in cattle increased. This implies that small-framed cows are more adapted to heat and nutritional stress compared to their large-framed counterparts. This can be attributed the facts that the rate of heat transfer between cows and the environment is proportional to the body surface area (Alfonzo *et al*., 2016). The large the body surface area the higher the amount of heat the cows absorb from the environment when environmental temperatures are high (Alfonzo *et al*., 2016). Scasta *et al*.

(2015a) suggested that small-framed cattle have less heat tolerance than their large-framed counterparts because of differences in metabolic rate. Metabolic heat production in cows is a function the size of the internal surfaces of their digestive organs. The larger the frame size, the larger the size of the internal surfaces of their digestive organs and, thus, the more metabolic heat is produced (Gillooly *et al*., 2001). The observed low adaptation to heat stress in large-framed cows as indicated by high HCT, MCHC and MPV levels could, therefore, be due to high metabolic heat production by these animals. Basing on our findings, low heat absorption from the environment coupled with low metabolic rate and, thus, reduced heat production helps to maintain heat balance in small-framed cows. Small-framed cattle are, therefore, suitable for hot environments.

The finding that large-framed cows had high RDW levels could be an indication that they were nutritionally stressed. High RDW levels in blood of cattle are mainly caused by poor nutrition (Roland *et al*., 2014). In agreement to our findings Zindove *et al*. (2015) reported that, unlike their small-framed counterparts, large-framed cows cannot meet their nutritional and water requirements under natural rangelands in drought prone areas. This can be attributed that small-framed animals have lesser maintenance requirements than large-framed animals hence they can easily meat their nutritional requirements (Jurado *et al*., 2015). Use of small-framed beef cattle with low feed requirements is, therefore, advised in drought prone areas. The relationship between PC3 (sheath height and dewlap size) and WBC, MCH, RDW and MCV may largely be a result of the interaction between heat resilience by the cows, health status and haematological profiles. High WBC, MCH, RDW and MCV all can indicate unhealthy and/or heat stressed cattle. Observed decrease in WBC, MCH, RDW and MCV as sheath height and dewlap size increased was expected. As the distance between the ground and the bottom of the cows' bellies increases, the cows are insulated from the ground when it's hot (Brown-Brandl, 2018). There are suggestions that the dewlap is responsible for dissipating heat in livestock (Bro-Jørgensen, 2016). As the surface area of the dewlap increases, the more heat is dissipated when environment temperatures are high (Bro-Jørgensen, 2016).

It can be concluded that the cows' hematological profiles were significantly affected by season and time of day with high WBC, HGb, HCT, MCH, MCHCH, MPV, NUET, LYMP and EOS found in cows during the afternoons of the hot-wet season. Black cows had more immuno- response related hematological profiles during the hot-wet season. The elevation of HCT, MCHC and RDW in cows occurred as the body depth, flank circumference and chest girth decreased, indicating a greater capacity of cows characterised by deep bodies, large flanks and chest

girths to withstand hydric, heat and nutritional stress in drought prone areas. Increase in HCT, MCHC, RDW and MPV as frame size of cows increased resulted in a greater capacity to meet nutritional and water requirements by small-framed cows under dry rangelands. Decrease in dewlap size and sheath height caused decrease in WBC, MCH, RDW and MCV in cows kept under rangelands in drought prone areas. It is likely that small-framed cows with large thoracic capacities, large dewlaps and belly bottoms far away from the ground surface are able to maintain haematological normalcy under natural rangelands in drought prone areas. It is, however, important to note that bred cows are important to the productivity and profitability of the cow herd. There is, therefore, need to establish reference hematological values for pregnant beef cows and explore more on the relationship between these conformation traits and hematological profiles of pregnant cows.

# Acknowledgements

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