EVALUATION OF HAEMATOLOGICAL PARAMETERS IN KATJANG AND BOER GOATS (IN DIFFERENT TIME PERIODS)

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ABSTRACT

This study was conducted in the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah (UMS) to study the haematological parameters between the local Katjang and Boer crossbreed goats. The aim of this study was also to compare the effect of haematological parameters of the goats at different time periods. A total number of twenty female goats were used in this study and divided into two breeds which were [Katjang (n= 10) and Boer (n= 10)]. Blood samples were collected in the morning (6 -8 a.m.), afternoon (12 noon - 2 p.m.) and evening (4 - 6 p.m.). The blood samples were analysed for haematological parameters using Auto Haematology Analyzer. For each period, ambient temperature and relative humidity were recorded by means of a data logger. The results obtained for Katjang goats in this study showed that there was no significant difference ($p>0.05$) of all haematological parameters at different time periods except for the composition of MCHC (298.63±10.48) which showed a significant different ($p<0.05$). On the other hand, the result obtained for Boer goats in this study showed that there was no significant difference ($p>0.05$) of haematological parameters in the effect of three different time periods. In the effect of breed factor, this study resulted that the mean ± standard deviation of all haematological parameters in Katjang goats which were RBC (15.27±2.42), HGB (7.80±1.50), HCT (26.02±4.73), MCV (17.03±1.11), MCH (5.06±0.29), MCHC (299.1±10.86) and RDW (20.21± 0.97) were in a normal range except WBC (16.16 ± 4.86) which were out of normal ranges. In Boer goats, the mean ± standard deviation of RBC (17.20±2.90), HGB (9.29 ±1.10), HCT (29.38±4.36), MCV (17.23±2.10), MCH (5.47±0.45), MCHC (319.5±16.84) and RDW (20.50 ±1.79) also showed the normal range except for WBC that exceed the standard ranges which was 17.85 ± 5.26 respectively. This study also revealed that breed between local Katjang and crossbreed Boer had significantly influenced ($p<0.05$) on some of haematological parameters which were HGB (8.55± 1.29), MCH (5.27± 0.37) and MCHC (309.3±13.85). Haematological values for this study could serve as baseline information for comparison in physiology and health status of farm animals. It can be concluded that environmental factors and breeds had significant changes on some haematological parameters of goats.

PENILAIAN PARAMETER HEMATOLOGI ANTARA BAKA KAMBING KATJANG DAN KAMBING BOER SERTA PADA SELANG MASA YANG BERBEZA

ABSTRAK

Kajian ini dijalankan di Fakulti Pertanian Lestari (FPL), Universiti Malaysia Sabah (UMS) untuk mengkaji kesan parameter hematologi antara baka tempatan dan baka kacukan. Tujuan kajian ini juga ialah untuk melihat kesan parameter hematologi kambing pada tiga jangka masa yang berbeza. Sebanyak dua puluh kambing telah digunakan dalam kajian ini dan dibahagikan kepada dua baka iaitu [Kambing Katjang (n=10) dan Boer (n=10)]. Sampel darah telah di ambil pada waktu pagi (6 -8 pagi), petang (12 tengah hari - 2 petang) dan petang (4-6 petang) kemudian dianalisis untuk semua parameter hematologi. Bagi setiap tempoh, suhu dan kelembapan relatif telah direkodkan dengan cara logger data. Keputusan yang diperolehi untuk kambing kambing Katjang dalam kajian ini menunjukkan bahawa tidak terdapat perbezaan yang signifikan ($p > 0.05$) bagi semua parameter hematologi pada tiga jangka masa yang berbeza kecuali untuk komposisi MCHC (298.63±10.48) yang menunjukkan perbezaan yang signifikan ($p < 0.05$). Sebaliknya, keputusan yang diperolehi untuk kambing Boer dalam kajian ini menunjukkan bahawa tidak terdapat perbezaan yang signifikan ($p > 0.05$) parameter hematologi dalam kesan tiga masa yang berbeza. Dalam kesan faktor baka, kajian ini menunjukkan bahawa min±sisihan piawai bagi semua parameter hematologi di Kambing Katjang iaitu RBC (15.27 ± 2.42), HGB (7.80 ± 1.50), HCT (26.02±4.73), MCV (17.03 ± 1.11), MCH (5.06 ± 0.29), MCHC (299.1 ± 10.86) dan RDW (20.21 ± 0.97) adalah dalam julat yang normal kecuali WBC (16.16 ± 4.86) yang berada di luar julat yang normal. Di kambing Boer, min ± sisihan piawai RBC (17.20 ± 2.90), HGB (9.29 ± 1.10), HCT (29.38 ± 4.36), MCV (17.23 ± 2.10), MCH (5.47±0.45), MCHC (319.5 ±16.84) dan RDW (20.50 ± 1.79) juga menunjukkan julat normal kecuali WBC yang melebihi julat normal iaitu 17.85 ± 5.26 masing-masing. Kajian ini juga menunjukkan bahawa baka antara kambing Katjang tempatan dan kacukan Boer telah mempengaruhi dengan ketara ($p < 0.05$) pada beberapa parameter hematologi yang iaitu HGB (8.55 ± 1.29), MCH (5.27 ± 0.37) dan MCHC (309.3 ± 13.85). Nilai hematologi untuk kajian ini boleh dijadikan sebagai maklumat asas untuk perbandingan dalam fisiologi dan kesihatan status haiwan ternakan. Dapat disimpulkan bahawa faktor persekitaran dan baka mempunyai perubahan yang besar ke atas beberapa parameter hematologi kambing.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figures		Page

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
µL	Microlitre
ABGA	American Boer Goat Association
ANOVA	Analysis of Variance
BBGS	British Boer Goats Society
CBC	Complete Blood Count
C°	Celcius
EDTA	Ethyl Diamine Tetra Acetic acid
FAMACHA	Faffa Malan Chart
FAO	Food and Agriculture Organization
fL	femtolitre
FSA	Faculty of Sustainable Agriculture
GIN	Gastrointestinal Nematode
H^+	Hydrogen
H_0	Null hypothesis
H_A	Alternative hypothesis
HCT	Haematocrit
HGB	Haemoglobin
HTC	Humidity Temperature Clock
MCH	Mean Concentration Haemoglobin
MCHC	Mean Corpuscular Haemoglobin Concentration
MCV	Mean Corpuscular Haemoglobin
MMS	Malaysian Meteorological Service
MPV	Mean Platelet Volume
NRC	National Research Council
PCV	Packed Cell Volume
pg	Pictogram
PKC	Palm Kernel Cake
RAR	Research Animal Resource
RBC	Red Blood Cells
RDW	Red Cell Distribution Width
RM	Ringgit Malaysia
SAS	Statistical Analysis System
THI	Temperature Humidity Index
UMS	Universiti Malaysia Sabah
WAD	West African Dwarf
WBC	White Blood Cells

CHAPTER 1

INTRODUCTION

1.1 Background

By the year 2050, the growth of the world's population is predicted to reach 9 million and demand for livestock products is expected to increase significantly in tandem with alongside rising health and safety concerns (UBM, 2015). In 2007, Malaysia imported 16,303 tonnes of goat meat (chevon) value at RM 160 million (Kaur, 2010). Increasing population will give high probability that the import bill on goat meat will continue to rise. At the same time, demand for high quality animal proteins also increases. This will create opportunities for entrepreneur to venture into livestock production hence will reduce the import bill on meat production. Goat meat has mainly been neglected (Davendra, 2006). The gap between goat meat production and consumption has been growing wider compared to other meat sub-sector (Kaur, 2010).

Poor goat production in Malaysia is contributed by many factors. Poor husbandry, infection of disease, lack of superior breeds and imported breeds cannot survive and adapted well to Malaysian environment are the major constraints to increase goat population in Malaysia. In all animal, health management is important in Malaysia as there are a number of endemic disease. Department of Veterinary Services Malaysia is authority for health management. The most common problem of goats in general in Malaysia is endoparasite and in particular *Haemonchus spp.* (Shanmugavelu and Quaza, 2014). Endoparasite and many infection will cause changes in the blood profile of the animals. To solve this problem, farmer and entrepreneur must take into consideration about health management and the control measure to prevent infection of diseases.

Haematology refers to the study of the numbers and morphology of the cellular elements of the blood (Manual, 2015). Blood consists of the red cells (erythrocytes), white cells (leucocytes), and the platelets (thrombocytes). Blood act as a pathological reflector of the status of the exposed animals to toxicants and other conditions. The examination of blood provides the opportunity to clinically investigate the presence of metabolites and other constituents in the body of animals and it plays a vital role in the physiological, nutritional and pathological status of an animal (NseAbasi and Mary, 2014). Haematological values could serve as baseline information for comparison in conditions of nutrient deficiency, physiology and health status of farm animals (Daramola *et al.,* 2005).Blood parameter profile as animal response indicators can serve as the basis for diagnosis, treatment, and prognosis of diseases (Otto and Bagasse, 2000; Ndlovu and Chimonyo, 2007). Haemtological studies are useful in the diagnosis of many diseases as well as investigation of the extent of damage to blood.

Blood constituents change in relation to the physiological conditions of health (Togun, *et al.,* 2007). These changes are of value in assessing response of animals to various physiological situations (Khan and Zafar, 2005). According to Afolabi *et al.* (2010), changes in haematological parameters are often used to determine various status of the body and to determine stresses due to environmental, nutritional and pathological factors.Haematological measurements have been used to identify constraints on productivity in beef cattle (Grunwaldt *et al.,* 2005). Red blood cells (RBC), white blood cells (WBC) or leucocytes, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) are haematological component in monitoring feed toxicity especially with feed constituents that affect the blood as well as the health status of farm animals (Oyawoye and Ogunkunle, 2004).

In a study conducted by Addass *et al.* (2012) observed that factors such as age, nutrition, health of the animal, degree of physical activity, sex and environmental factors affect blood values of animals. In addition, blood pictures of animals might be influenced by certain factors such as management,nutrition, sex, breeds, age , disease and stress factor (Schalm *et al.,* 1975). Environmental factors is one of the factor that affect the blood values of the animal. Environmental factor or ecological factor is any factor, whether abiotic or biotic, that influences living organisms. Abiotic factors include ambient temperature, amount of sunlight, humidity and pH of the water soil in which an organism lives, while biotic factors include the availability of food organisms and the presence of conspecifics, competitors, predators, and parasites (Giplin, 1996). This means that the values of animals blood will be different according to environments. Relative humidy and temperature are environmental monitor and main factors in changing the blood values of animals. Therefore, these factors must be acknowledged by people such as farmers and veterinarians who wishes to draw blood from animals in order to identify the health status of their animals.

1.2 Justification

To date, there is still lack of data on haematological parameters between local and cross breeds of goats and also the effect of environmental factors in Malaysia. Therefore, this study is proposed to provide baseline data in the effect of different relative humidity and temperature based on three time periods on Katjang and Boer goats. This study also is proposed to provide baseline data on haematological parameters between breeds as reference for further research.

1.3 Objectives

1. To evaluate any differences in haematological parameters during the three different time periods of Katjang and Boer goats

2. To monitor any differences in haematological parameters between breeds of Katjang and Boer goats

1.4 Hypothesis

1. H_o - There is no significant difference in haematological parameters at three different time periods and between breeds of Katjang and Boer goats

H_A - There is significant difference in haematological parameters at three different time periods and between Katjang and Boer goats

CHAPTER 2

LITERATURE REVIEW

2.1 Goats

2.1.1 Katjang Goats

Katjang is also known as Kacang, Katchang and Kambing Kampung. In Malaysia, Katjang is the only indigineous breed of goat (Munirah *et al.,* 2015). Katjang goat has morphological characteristics of a thin, black and brown coloured coat sometimes with white patches. Katjang is a meat type animal. Katjang males have mature weight of 25 kg and average height at withers of 63 cm while females have mature eight at 20 kg and average height at ithers is 56 cm respectively (Munirah *et al.,* 2015). Katjang goat is very well adjusted to the local ecosystem and requires low inputs. As an indigeneous goat, Katjang possesses the natural characteristics of heat and disease tolerance in an equatorial, hot- humid climate. Katjang is generally tolerant to gastrointestinal parasites and this genetic characteristics can be exploited for other breeds (Shanmugavelu and Quaza, 2014). With climate change and increasing pressures on land use, Katjang goat may become the goat of choice for future challenging production environments (Munirah *et al.,* 2015). Amie *et al.* (2004) reported that to avoid loss of genetic diversity, implementation of appropriate breeding programmes and strategies are necessary particularly in the indigenous Katjang goat breed.

2.1.2 Boer Goats

Boer goats were originated from South Africa and the earliest recorded goats in Africa were bought to western Uganda by the Black Nations as early as AD 1200. Boer goats were developed in Southern Africa by breeding these indigeneous stock to European imports. (ABGA, 2015). The boer goats were developed specifically for meat and it is a stocky animal with short legs, broad chest and thick rump (BBGS, 2015). Apart from the Boer's distinguished colours of chestnut head and white body and its evident docility, the main characteristics are its body conformation, which makes the Boer the first meat-producing breed of goat in the world. Boer goat are very adaptable and could survive the varied condition the African landscape while still maintaining a high birth rate, high survival rate, and a marketable meat carcass (ABGA, 2015). The breed has adapted well to the harsher northern climate and can be out wintered in lowland areas of the British Isles (BBGS, 2015). In a study conducted by Amie *et al.* (2004) Boer, Jamnapari and Savanna which are introduced breeds are well adapted in Malaysia.

2.2 Climate of Malaysia

The climate of Malaysia is driven by its equatorial position, extensive coastlines on tropical seas and monsoonal winds because Malaysia is situated between one and six degrees North latitude, Malaysia has an equatorial climate with uniformly high temperatures, high humidity, relatively light winds, and abundant rainfall throughout the year (Mark, 2011). The main causes of climatic variation within Malaysia are differences in altitude and the exposure of the coastal lowlands to the alternating southwest and northeast monsoon winds. The southwest monsoon winds blow from April to September and the northeast monsoon winds blow from November to February.

2.3 Relative Humidity

Relative humidity is the ratio of the amount of water vapor in the air to the amount of water vapor air can hold at that temperature (Elovitz, 1999). Different measures of humidity quantify different physical properties of the mixture of water vapour (moisture) and air. Understanding how moist air behaves requires understanding those measures of humidity (Giplin, 1996). In Malaysia, the relative humidity is between 60-95 % (MMS, 2006). Humidity varies more throughout the day than it does annually (Mark, 2011). Average of rainfall occurs throughout the year from 2,000 to 2,500 mm a year (MMS, 2006). Malaysia has two mains season which are wet and dry seasons. In Peninsular Malaysia, normally between September and December is the wet season whilst the dry season is between January and March. In East Malaysia which are Sabah and Sarawak , the main wet season is normally from October to February. Sheep and goats rely on evaporative cooling from the respiratory tract. High humidity associated with high temperatures is stressful to the animals as it interferes with their ability to regulate body temperature. If indoor temperatures rise above 30° C a comfortable environment can be maintained by keeping the relative air humidity below 60% (FAO, 2015).

2.4 Temperature

Temperature is the degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch. Temperature is a measure of the average heat or thermal energy of the particles in a substance. Since it is an average measurement, it does not depend on the number of particles in an object. In that sense it does not depend on the size of it. Malaysia has uniformly high temperatures throughout the year. In most areas the average maximum and minimum temperature per month vary less than 2°C annually. Temperature can range daily between 5°C to 10°C near the coast and from 8° C to 12°C inland (Mark, 2011). For example the monthly average maximum temperature ranges from 32- 33° C year in Kuala Lumpur, 31- 33° C in Penang, 29- 33° C in Kuching, and 30- 32° C in Labuan. The temperature in Malaysia is fairly uniform throughout the year and fluctuates between 23-34° C (MMS, 2006). Malaysia lies within the humid tropics characterized by warm temperatures (mean >17 °C) and abundant rainfall (250-2000 mm) which exceed evapotranspiration (Viera and Scariot, 2006).

2.5 Temperature Humidity Index (THI)

Temperature Humidity Index (THI) is a measure combined effects of environmental temperature and relative humidity (Dairy Australia, 2015). It is a useful and easy way to assess the risk of heat stress. THI also used measure of the degree of discomfort experienced by an animal in warm weather. Some of important points should be made about the THI are THI does not account for solar radiation or air movement. Those two factors, along with air temperature and relative humidity, determine the heat gained and lost between the cow and the environment (Dairy Australia, 2015). THI is still a useful and easy way to assess and predict the risk of heat stress; however, it is wise to be conservative.

2.6 Animal Environmental

Small ruminants are well adapted to extreme temperatures, with their fleece or coats providing an insulative layer which protects them from cold and heat (Geoff and Justin, 2000). At the upper and lower critical temperatures the physical regulation will not be sufficient to maintain a constant body temperature and the animal must, in addition, decrease or increase its metabolic heat production. (FAO, 2015). The body temperature of most domestic animals is considerably higher than the environmental temperature to which they are exposed most of the time. They maintain their body temperatures by balancing internal heat production and heat loss to the environment. (FAO, 2015). A further decrease or increase in temperature will eventually bring the temperature to a point beyond which not even a change in heat production will be sufficient to maintain homeothermy.The normal body temperature of goat is 38.7-40.7 (FAO, 2015). The comfort zone of goats is wide, ranging from 0-30° C (FAO, 2015). If animals are recovering from surgery, it is advisable to keep the ambient temperature slightly higher than normal as physiological thermoregulation is inadequate during the first 24 hours following anaesthesia. Under such conditions a temperature of 20-28 °C is recommended. The neonatal lamb and kid are also most comfortable within this temperature range (Alexander, 1997).

2.7 Haematological Value of Farm Animals

Table 2.1 Haematological Values for Farm Animals

	Swine	Sheep	Cow	Rabbit	Guinea Pig
HCT (%)	32 – 50	24 – 45	24 – 48	30 – 50	37 – 48
HGB (g/dl)	10 – 16	8 – 16	8 – 15	10 – 15	11 – 15
MCV (fl)	50 – 68	23 – 48	40 – 60	78 – 95	67 – 77
MCH (pg)	17 – 23	8 – 12	11 – 17	-	-
MCHC (g/dl)	30 – 36	31 – 38	30 – 36	27 – 37	30 – 34
WBC (x1000)	7 – 20	4 – 12	4 – 12	4.5 – 11	5 – 8.9
Diff (%)					
Lymphocytes	40 – 60	40 – 70	40 – 70	40 – 80	39 – 72
Monocyte	2 – 10	0 – 6	1 – 6	1 – 4	2 – 6
Eosinophils	0 – 10	0 – 10	0 – 4	0 – 4	0 – 5
Basophils	0 – 2	0 – 3	0 – 2	1 – 7	0 – 3

Source : Research Animal Resources [RAR] (2009).

2.7.1 Haematological Values for Adults Goats

Table 2.2 Haematological Values for Adults Goats

Parameters	Units	Values
WBC	($10x^9$/L)	4.0-13.0
RBC	($10x^9$/L)	8.0-18.0
HGB	(g/dL)	8.0-12.0
HCT	(%)	22-38
MCV	(fL)	16-25
MCH	(pg)	5.2-8.0
MCHC	(g/dL)	300-360
RDW	(%)	21-28
Platelets	($10x^3$µl)	300-400
Neutrophils	(cells/µl)	700-7,600
Lymphocytes	(cells/µl)	2500-12000
Monocytes	(cells/µl)	70-570
Eosinophils	(cells/µl)	0-2000
Basophils	(cells/µl)	0-250

Source: Plumb (1999)

2.8 Complete Blood Count (CBC)

A complete blood count (CBC) is a common blood test, providing information on general health status and is a tool for checking disorders such as anemia, infection and thrombocytopenia. Complete blood counts are done to monitor overall health, to screen for some diseases, to confirm a diagnosis of some medical conditions, to monitor a medical condition, and to monitor changes in the body caused by medical treatments (Clinic, 2015). CBC provides detailed information about three types of cells including white blood cells (WBC), red blood cells (RBC), and platelets. All of which may be increased or decreased with various conditions (TBN, 2015). Abnormally high or low counts may indicate the presence of many forms of disease, and hence blood counts are amongst the most commonly performed blood tests in medicine, as they can provide an overview of a patient's or animal's general health status. Blood counts of various types have been used for clinical purposes since the 19th century. Automated equipment to carry out complete blood counts was developed in the 1950s and 1960s (Verso, 1962). A complete blood count will normally include White Blood Cell (WBC), Red Blood Cell (RBC), Haemoglobin (HGB), Haematocrit (HCT), Mean Corpuslar Volume (MCV), Mean Corpuslar

Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC) and lastly, Red blood cell distribution width (RDW).

2.8.1 White Blood Cell (WBC)

The major functions of the WBC and its differentials are to fight infections, defend the body by phagocytocis against invasion by foreign organisms and to produce or at least transport and distribute antibodies in immune response. Thus, animals with low white blood cells are exposed to high risk of disease infection, while those with high counts are capable of generating antibodies in the process of phagocytocis and have high degree of resistance to diseases (Soetan *et al.,* 2013) and enhance adaptability to local environmental and disease prevalent conditions (Isaac *et al.,* 2013). The white blood cell (WBC) count is a count of the number of white blood cells per volume of blood. Both increases and decreases can be significant. Depending on the laboratory's report forms, white blood cells are reported as thousands in a microliter of blood for example 5,000/µL or 5.0×10^3/µL or as millions in a liter of blood such as 5.0×10^9/L (TBN, 2015). The white blood cell differential looks at the types of white blood cells present. There are five different types of white blood cells, each with its own function in providing protection from infection. The differential classifies a animal's white blood cells into each type: neutrophils, lymphocytes, monocytes, eosinophils, and basophils (TBN, 2015).

2.8.2 Red Blood Cell (RBC)

Red blood cells (erythrocytes) serve as a carrier of haemoglobin. It is this haemoglobin that reacts with oxygen carried in the blood to form oxyhaemoglobin during respiration (Chineke *et al.,* 2006). According to Isaac *et al.* (2013) red blood cell is involved in the transport of oxygen and carbon dioxide in the body. Thus, a reduced red blood cell count implies a reduction in the level of oxygen that would be carried to the tissues as well as the level of carbon dioxide returned to the lungs (Ugwuene, 2011). The red blood cell (RBC) count is a count of the number of red blood cells per volume of blood. Both increases and decreases can point to abnormal conditions. Depending on the laboratory's report forms, red blood cells are reported as millions in a microliter of blood (4,250,000/µL or 4.25×10^6/µL) or as millions in a litre of blood (4.25×10^{12}/L) (TBN, 2015). The mature RBC is a biconcave disk. This unique shape allows for a greater surface area for oxygen to combine with HGB. Haemoglobin (HGB) is the oxygen-carrying protein of the RBC, which accounts for approximately 90% of the cells' dry weight. RBCs have no nucleus, and therefore cannot divide (Beverly and Parker, 2003).

Information about the RBC is obtained with a CBC but can also be obtained separately with a hemogram. The RBC count is the part of the CBC that determines the number of RBCs found in a cubic centimeter of blood. It is also expressed in International Units, which is the number of RBCs per liter of blood (Beverly and Parker, 2003).

2.8.3 Haemoglobin (HGB)

Haemoglobin's primary function is to carry oxygen to the cells and remove carbon dioxide from the cells. HGB is a complex protein made up of heme and globin. It is produced in the immature RBC. Synthesis stops once the cell matures in circulation. There are approximately 300 million molecules of HGB in one RBC. HGB is measured in grams per deciliter (Beverly and Parker, 2003). HGB saturated with oxygen is called oxyhemoglobin. One should note that oxygen saturation is a measure of the amount of oxygen combined with HGB in the blood and should not be confused with the partial pressure of oxygen (PO_2), which is the amount of oxygen dissolved in plasma. HGB also functions as a buffer for extracellular fluid and is capable of accepting hydrogen (H^+) ions to prevent the buildup of H^+ ions in the blood (Beverly and Parker, 2003). Haemoglobin has the physiological function of transporting oxygen to tissues of the animal for oxidation of ingested food so as to release energy for the other body functions as well as transport carbon dioxide out of the body of animals (Omiyale *et al.,* 2012).

2.8.4 Haematocrit (HCT)

Haematocrit (HCT) or also known as Packed Cell Volume (PCV) which is the percentage (%) of red blood cells in blood (Purves *et al.,* 2003). According to Isaac *et al.* (2013) haematocrit is involved in the transport of oxygen and absorbed nutrients. Increased haematocrit shows a better transportation and thus results in an increased primary and secondary polycythemia. "Hematocrit" means "to separate blood." HGB and HCT levels parallel, in that HCT levels are 3 times the HGB level (Beverly and Parker, 2003). This relationship is altered if RBCs are abnormal in size or shape or if the synthesis of HGB is defective. The RBC count, HCT, and HGB are closely related. Alterations in one are usually associated with alterations in the other. As such, increases and decreases in each are discussed together (Beverly and Parker, 2003).

2.8.5 Mean Corpuscular Volume (MCV)

Mean corpuscular volume (MCV) is a measurement of the average size of the red blood cells (RBC). The MCV is elevated when RBC is larger than normal (macrocytic), for example in anemia caused by vitamin B12 deficiency. When the MCV is decreased, RBC is smaller than normal (microcytic) such as is seen in iron deficiency anemia (TBN, 2015). MCV describes the RBC by size or volume. This measure uses the size of the RBC to identify possible causes of anemia as well as other disorders. The MCV classifies RBCs as microcytic, normocytic, and macrocytic. Microcytic cells are small or undersized. They are seen with iron deficiency anemia and thalassemia (Beverly and Parker, 2003). In hemorrhagic or hemolytic anemias, the decrease in oxygencarrying capacity is caused by a decrease in the number of RBCs; the cells that remain are normal in size, thus the RBCs are normocytic. RBCs that are macrocytic are large or oversized. These RBCs are seen in patients with pernicious or folate deficiency anemia. MCV is a calculated value obtained by dividing the HCT by the RBC count (Beverly and Parker, 2003).

2.8.6 Mean Corpuscular Haemoglobin (MCH)

This value is the index that measures the average weight of HGB in the RBC. An alteration in MCH tends to track along with the MCV. For example, a smallsized cell will have less HGB within it compared with a large-sized cell, therefore its weight would be lower. Decreases are related to microcytic anemias, and elevations are related to macrocytic anemias. Therefore, the MCH adds little information independent of the MCV (Beverly and Parker, 2003). According to Peters *et al.* (2011) previous reports stated that Packed Cell Volume (PCV), haemoglobin (HGB) and Mean Corpuscular Haemoglobin (MCH) are major indices for evaluating circulatory erythrocytes, and are significant in the diagnosis of anaemia and also serve as useful indices of the bone marrow capacity to produce red blood cells as in mammals (Awodi *et al.,* 2005). Mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration indicate blood level conditions. A low level is an indication of anaemia (Aster, 2004).

2.8.7 Mean Corpuscular Haemoglobin Concentration (MCHC)

Mean corpuscular hemoglobin concentration is measure of the average concentration of HGB in the RBC per unit volume. RBCs that contain less HGB are hypochromic and are a pale colour. Normal-coloured cells with normal amounts of HGB are called normochromic, and hyperchromic cells have an increased concentration of HGB and are bright red in colour (Garrett, 2002). Decreased values point to hypochromasia, decreased oxygen-carrying capacity because of decreased hemoglobin inside the cell. Hypochromasia is seen in iron deficiency anemia and in thalassemia (TBN, 2015).

2.8.8 Red cell distribution width (RDW)

Red blood cell distribution width (RDW) is routinely performed as part of a complete blood cell count and quantifies the variability in size of circulating red blood cells (anisocytosis), defined as the standard deviation of erythrocyte size divided by the mean corpuscular volume (MCV) (Mireille *et al.,* 2011). Red cell distribution width (RDW) is a calculation of the variation in the size of RBCs. In some anemias, such as pernicious anemia, the amount of variation (anisocytosis) in RBC size (along with variation in shape – poikilocytosis) may help evaluate the severity of a condition (TBN, 2015). Red cell distribution width (RDW), one of many routinely examined parameters, shows the heterogeneity in erythrocyte size (Yasuko *et al.,* 2013). It is used clinically to differentiate different types of anemia. Recent studies have reported the association between high RDW levels and increased mortality in the general population (Patel *et al.,* 2009).

2.9 Auto Hematology Analyzer Machine (Blood Analysis)

BC-2800 Auto Hematology Analyzer Mindray is a compact, fully automatic hematology analyzer with 19 parameters for complete blood count (CBC) test and micro sampling technology. This machine will analyze three-part differentiation of WBC which are monocytes, granulocytes and lymphocytes, 19 parameters includes red blood cells (RBC), haemoglobin (HGB), haematocrit (HCT), platelet and Mean Platelet Volume (MPV). This machine also provides three histograms with two counting modes which are whole blood and prediluted. This machine is able to analyze 30 samples per hour and the storage for up to 20,000 sample results (including histograms).

2.10 FAMACHA© system

2.10.1 Background

The FAMACHA© system was developed by three South African researchers against the backdrop of major anthelmintic resistance in South Africa (Van and Bath, 2002). It is to estimate the level of anemia in sheep and goats associated with barber pole warm (*Haemonchus contortus sp.)* infection and use that information to make deorming decisions (Anne and Katherin, 2014). Barber pole warm is the most important gastrointestinal nematode (GIN) parasite affecting sheep and goat production on pasture. It has a small "tooth" that

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