Effects of supplementary diet protein on growth performance and reproductive health of Tswana goats

M S Tsheole

[Orcid.org 0000-0003-3782-6757](https://orcid.org/0000-0003-3782-6757)

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Promoter: Prof M Mwanza

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DECLARATION

I, Mpho Sylvia Tsheole, declare that the thesis entitled "Effects of supplementary diet protein on growth performance and reproductive health of Tswana goats", hereby submitted for the degree of Doctor of Philosophy in Agriculture (Animal Health) has not previously been submitted by me for a degree at this or any other university. I further declare that this is my own work in design and execution and that all materials contained herein have been duly acknowledged. The research reported in this thesis does not contain any person's data, pictures, graphs or other information unless specifically acknowledged as being sourced from those persons.

Signed: ________________________ Date: ____________________

Mpho Sylvia Tsheole (Candidate)

As the candidate's supervisors, we agree to the submission of this thesis.

Signed: _______________________ Date: ____________________

Professor Mulunda Mwanza (Promoter)

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DEDICATION

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ABSTRACT

The aim of the study was to evaluate of nutritional supplementation environments of the North West Province of South Africa. To achieve this, several objectives were identified.

The first objective was to assess the impact of goats' farming and challenges faced by farmers in rural areas of Mahikeng Local Municipality, North West Province. Data were randomly collected by interviewing 75 farmers from three villages (Ramatlabama 600, Tsetse and Lokaleng) using a structured questionnaire. The interviews focused on production systems, management and marketing strategies of Tswana goats in semi-arid areas around Mahikeng, North West Province. Descriptive statistics were generated using Statistical Package for the Social Sciences (SPSS) version 22. Nearly 60% of farmers sold animals without weighing and were also affected by low market value for livestock. About 29% of goat owners experienced abortions due to droughts and mineral deficiencies. Other factors included poor housing and low soil fertility for forage production. In addition major constraints for goat productions were as follows: stock theft (45%); malnutrition (33%); and diseases (32%). A significant correlation ($P<0.05$) was observed between grazing system (communal grazing areas) and access to veterinary services. There is the need to empower farmers with knowledge and skills to improve their farming management practices and marketing. In addition, there is need to improve access to veterinary care to reduce diseases and the mortality of kids in rural areas. This will make significant contribution towards addressing the issue of goat management to obtain optimum production under the extensive management system.

The aim of the second experiment was to determine the impact of protein supplementation on goat reproductive performance, health and on blood and hormonal parameters. To achieve this objective, an experiment was conducted using 24 weaned female Tswana goats (three months of age). The experiment was done completely randomized. Blocking was done according to body weight and animals were allocated into three treatment groups of eight goats per treatment and their feeding regime consisted of protein (23.51%) and energy (8.55%) per kg of the body weight. The first group was given Maintenance protein requirement (Diet 1); the second group was given twice the Maintenance requirement (Diet 2) and the third group was fed three times the Maintenance X3 (Diet 3). All animals had *ad lib* access to the basal diet of hay, water and salt. Blood samples were collected and serum

metabolites and reproductive hormones measured at the beginning of the experiment and weekly. One-way analysis of variance (ANOVA) was carried out on blood nutritional metabolites, hormonal, growth and reproductive performance data using the General Linear Model (GLM) procedure of the Statistical Analysis System. The results obtained showed that different levels of protein supplementation had significant (P<0.05) effects on glucose, albumin, albuglobulin and urea levels. The level of progesterone in Diet 2 was significantly higher with the value of 13.45 ppb, while for the other weeks, no significant effects were observed from week 0 up to week 20. The use~~s~~ of high levels of dietary protein supplements boosted the levels of progesterone in the study. The body weights reported in the study (in all three treatment groups) increased with advancement in pregnancy until birth ranging from 1.40 kg to 9.46 kg. The high levels of dietary protein influenced the levels of blood progesterone, body weight and other blood metabolite parameters. The levels of progesterone were significantly influenced by the protein diet. Treated animals showed higher concentrations compared to the control group. There was a significant difference (P<0.05) in body weights between three treatments with animals supplemented with protein, having higher body weights as compared to the control group. There was also a significant influence of protein supplementation on the twinning of kids. A significant difference (P<0.05) was observed between different treatments with 50% of animals that received high concentrations of protein, having twins, while no twining was registered in the other two treatment groups. In addition, protein supplementation in Tswana goats showed a significant (P<0.05) effect between treatments from different groups (regarding live weight of kids). Feeding of goats with high protein diet significantly (P<0.01) increased growth (Diet 3 vs Diet 1) compared to low protein diet. In conclusion, supplementation with three times maintenance level improved growth and reproductive performance and health and concentrations of serum metabolites and hormones, which subsequently, improve~~d~~ reproductive hormones (progesterone) and some blood metabolites (blood glucose, albumin total protein and albumin) during oestrus cycle.

These findings provide important information in terms of the design of nutritional strategies to increase reproductive outputs, mainly through precision supplementation or focus feeding. Supplementation of high protein diet (three times maintenance) to Tswana goats increased growth performance and reproduction of goats. Despite the cost of the source of protein in the diet of animals, there is need to educate farmers on feed formulations, balanced feeding to

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animals to increase productivity. To optimise the productive potential of Tswana goats, it is important to implement the reproductive management programme for the improvement of reproductive aspects of goats. It could, therefore, be concluded that improved feeding with better management could ensure improvement in the reproductive performance of Tswana goats.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemistry
BUN	Blood Urea Nitrogen
CHO	Cholesterol
CIP	Cataloguing-in-Publication
CRD	Complete Randomised Design
CRBD	Completely Randomised Block Design
DAFF	Department of Agriculture, Forestry and Fisheries
GLM	General Linear Mode
HPLC	High Performance Liquid Chromatography
INW	Invest North West
LIP	Lipase
RPM	Revolutions Per Minute
SAS	Statistical Analysis System
TP	Total Protein
TRIG	Triglycerides
PDIFF	Probability of Difference

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Tswana goats are characterised by horns, wattles and beards. The coat colours are white, black and white, brown and white while the hair structure can be short, long, or smooth. The world population of goats is estimated at 746 million (FAOSTAT, 2010), with 96% of these kept in developing countries. In South Africa, however, 5% of the country's goat population is kept under small scale conditions (Shabalala and Mosima, 2002).

Indigenous goats are widely spread in most countries in Southern Africa and, are nutritionally, economically and socially important to rural households. However, productivity is constrained by shortage of good quality feed, especially during the long dry season (Brown *et al*., 2016). Tswana goats are economically important livestock to the common people in rural communities around Mafikeng (Schoeman *et al*., 2010). Goats have contributed to people's livelihoods in many ways, and their contribution tends to be particularly important for needy people. These include meat, skin, manure and sources of income (Gebrewahid *et al.*, 2012).

Bakunzi *et al.* (2012) observed in his study that small ruminants constitute a major source of protein for human nutrition in tropical and subtropical regions. However, production levels are low due to a number of factors such as poor nutrition, diseases, parasitism and low levels of management. While poor nutrition is considered the most critical factor, diseases and parasitism are a major source of economic loss (Coop and Holmes, 1996; Ng'ang *et al.*, 2009).

Optimising reproductive efficiency and cost effectiveness are common goals for good husbandry in various production systems (Invest North West Summary Report, 2013). Nutritional imbalances affect the reproductive performance of does and other ruminants (Haenlein, 1987). Reproductive performance of does is a major determinant of productivity and economic viability of communal and commercial goat farms. Underwood and Suttle (1999) reported that in many parts of the world, animal productivity is limited by shortage of energy and protein, infectious and parasitic diseases and genetic inadequacies in the animal. With the rectification of these limitations, local mineral deficiencies and imbalances become also critical for the production of goats (Underwood and Suttle, 1999). Hence, the need to balance both nutrition and minerals to ensure growth and production.

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Estrada-Cortes *et al*. (2009) highlighted that reproduction in goats is described as seasonal, spontaneously ovulating or polyestrus. In addition, latitude, climate, breeds, physiological state, breeding system and photoperiod may influence the onset of breeding. Fatet *et al*. (2011) postulate that production out of natural breeding season, is possible through hormonal treatments and manipulation of photoperiod (by the male effect or nutritional strategies). Nutrition rather than photoperiod, plays an important role in the induction of oestrus activity and seasonality of breeding in tropical regions (Singh and Singh 1974; Riera, 1982). Energy balance has a major effect on reproductive performance, affecting age at puberty (Day *et al*., 1986; Moran *et al.,* 1989*;* Kinder *et al.,* 1995).

Fertility is impaired by several factors including: droughts seasons; poor pastures; switch to lower quality feedstuffs; and any condition that lowers feed intake (Fatet *et al.* (2011) Energy supply below the required level for maintenance and pregnancy, affects the survival of kids (Fatet *et al*. 2011). The relationship of protein to reproduction is similar to that of energy, and the two nutrients interact to a large extent Fatet *et al*. (2011). Goetsch *et al*. (2011) posit that compared to animals on pastures, those fed with concentrate-based diets have higher growth rates, dressing percentage and carcass quality. Furthermore, Goetsch *et al*. (2011) reported that diets could affect the characteristics of carcass and growth performance of young goats.

Management around the pre-parturient period could affect the overall reproductive status of the recovering doe following birth (Leroy *et al.,* 2010). Leroy *et al*. (2010) confirmed that when energy supplies are adequate, a shortage of protein will impair fertility, delayed onset of puberty, lengthen anoestrus of goats and result in weak expression of oestrus if it does occur. Yugal *et al*. (2013) affirmed that mineral deficiencies, primarily phosphorus, reduce the reproductive performance of does under grazing conditions. Mineral concentrations in forages consumed by goats vary greatly depending on factors such as soil and seasons of the year (Yugal *et al.,* 2013). Although goats can tolerate moderate body weight loss at mating and still get pregnant, more severe changes in energy intake during pregnancy markedly affect foetal survival (Yugal *et al*., 2013). As a result, abortions and stillbirths occur and are major causes of economic loss for the goat industry under intensive and extensive conditions (Melado *et al*., 2006). There is limited data on challenges faced by goat farmers and on the effects of supplementary protein, energy and minerals on performance and reproductive health of Tswana goats in Mafikeng area, North West Province, South Africa.

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1.2 PROBLEM STATEMENT

Productivity of goats in the North West Province is generally considered to be low due to poor nutrition, which in turn, negatively affects reproductive performance and health. Mokolopi and Beighle (2006) argued that poor nutrition, especially shortage of minerals such as phosphorus (P), calcium (Ca) and magnesium (Mg), is associated with poor production and nutritionally-associated diseases. Indeed, poor reproductive performance and health of grazing animals has been attributed to low intake of protein, energy and minerals (Smith and Chase, 2010). However, there is a general lack of knowledge among farmers on how to improve the productivity of goats.

1.3 JUSTIFICATION

Goat production could play an important role in economies and smallholder farmers in the North West province. However, seasonal fluctuations in the quantity and quality of feed constitute the greatest challenge in terms of maintaining animal productivity (Masikate 2010). The lack of adequate supplies of good quality livestock feed in the dry season produced at a competitive cost without jeopardizing household food security is the main constraint to the increase in livestock feed during the dry season and output. It is important to define the optimum inclusion level of protein, energy and mineral supplements in order to prevent under or overfeeding. Overfeeding negatively affects both the productivity of goats as well as profitability and, hence, sustainability of the goat production enterprise. On the other hand, nutrient deficiencies have a negative effect on reproduction health and growth performance of animals. It is, therefore, imperative that empirical studies be conducted to determine productivity responses of goats to changes in supplementary nutrient levels. These responses vary greatly with locality, goat breeds, physiological status and sources of nutrients.

1.4 HYPOTHESIS

The Null Hypothesis is that daily protein and energy supplementation have no effect on growth performance, reproduction and health of Tswana goats**.** The Alternate Hypothesis is that daily protein and energy supplementation will positively affect the growth performance and reproductive health of Tswana goats

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1.5 OBJECTIVES

The broad objective of the study was to assess the effect of nutritional supplementation on growth performance, and reproduction and health of goats reared in the semi-arid environment of the North West Province, South Africa.

The specific objectives of the study were to:

1. Determine management and production systems and their marketing channels as well as supplements for use by farmers in the semi-arid area for optimum productivity;

2. Determine the effect of incremental levels of protein supplementation on reproductive performance with regard to growth performance and health of female Tswana goats; and

3. Determine blood parameters, including reproductive hormones of female Tswana goats.

1.6 RESEARCH QUESTIONS

The following research questions were asked in the study:

1. Do the management, production and marketing channels used by farmers in the semi-arid area of Mahikeng improve productivity?

2. Does the supplementation of protein have any effect on performance and reproductive health of goats reared in extensive production in the study area? and

3. Does supplementation of protein affect blood parameters and reproductive hormones of female Tswana goats?

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CHAPTER TWO: LITERATURE REVIEW

2.1 PRODUCTION, BREEDING, CHARACTERISTICS AND MARKETING OF TSWANA GOATS IN SOUTH AFRICA

The characterisation of the genetic resources of local goats is assessed based on morphology qualities among breeds (Delgado *et al.,* 2001; Gizaw *et al.,* 2007).There are three indigenous goat ecotypes in South Africa. They are defined by their distinctive body conformation, coat colour and characteristics of hair type (Morrison, 2007). These include the Nguni type and Tankwa goat breeds found in the Northern Cape Province (Mdladla *et al*., 2017). The coat colour patterns of goats vary within and among the goat population. Rumosa Gwaze *et al*. (2009) highlighted that communal goat farmers market their goats at abattoirs, shops and leather craft workshops. However, government assists communal goat farmers of South Africa by forming entities such as the Umzimvubu goat projects, which facilitate the marketing of indigenous goats. In addition, Bakunzi *et al.*, (2012) also observed lack of organised marketing of goats in South Africa. Communal farmers resort to the informal way of marketing their goats where pricing is based on an arbitrary scale, with reference to visual assessment of the animal. However, evaluation of goat production systems, through identification and prioritisation of constraints is a prerequisite for planning and improving production. The aim of this study was to evaluate the effect of supplementary protein on growth and reproductive performance and the health of Tswana goats reared in extensive production systems.

2.2 IMPORTANCE OF TSWANA GOATS IN RURAL ECONOMIES IN SEMI-ARID AREAS

Tswana goats are important resources for poor rural farmers as they contribute to food security and poverty alleviation. Munau *et al*. (2017) reported that, Tswana goats are characterised as multi coloured, medium sized with long lopping ears, short coarse hair and are often bearded and horned. Although limited research has been conducted on the breed and production systems, the breed has valuable traits such as tolerance towards diseases, drought and heat (Nsoso *et al*., 2014). In addition, Adogla-Bessa and Aganga (2000), confirmed in their study that the Tswana goat breed can produce between 0.47 and 0.72 kg/day of milk.

For people who believe in traditional medicine and rites, goats are also important during burial rituals performed by traditional healers as they suck out the blood and wear the gall

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bladder as a headdress (Department of Agriculture, Forestry and Fisheries, 2012). Hellen (2005) reported that the characteristics to be considered when rearing goats depend on the main product, and should describe also, the ability of the animals to survive and reproduce. This includes the number of offspring weaned/year/female exposed to the male, annual death rates (each sex) and length of productive life (each sex). The main constraint is a prerequisite for planning and improving production. The reasons for keeping goats in the Taung and Kurumane district of the North West Province are milk, meat and social functions. In addition, goats play an important role in traditional ceremonies (Simela and Merkel, 2008). These authors also confirmed that goat skin is used for making drums, handles and for covering milk gourds in addition to its miraculous qualities. According to records of 2012, chevon produced amounted to R3.6 billion from 2002-2011, representing 12% of the whole country (Department of Agriculture, Forestry and Fisheries, 2012).

Different countries have different ways of managing goats. In Mozambique goats are supplemented with a variety of fruit trees, maize and cassava crop residues (Loforte, 2002). While, Loforte (2002) states that in Lesotho, in most communal areas, school children are responsible for herding goats. According to Wasson and Hall (2002), in Lesotho, men could be employed as shepherds. Webb and Mabolo (2004) also indicated that tethering of goats is common in Zambia, South Africa and Malawi.

2.3 CONSTRAINTS TO GOAT PRODUCTION IN SEMI-ARID AREAS

Farmers face several challenges in the process of livestock production. Among challenges faced by goat farmers, Kabir *et al*. (2004) moot that goat production in villages, following the traditional husbandry system, is often characterised by poor growth rates, high mortality and low reproductive rates. In addition, high mortality among kids and slow growth among those that survive are major constraints to goat production (Sebei *et al.*, 2004). Furthermore, the weaning percentage, which is a measure of survivability of kids, from birth to weaning, is low in communal areas.

Ben Salem and Smith (2008) and Githiori *et al*. (2006) in semiarid regions noted that the main constraints to goat farming in semiarid regions are high prevalence of diseases and parasites, low level management, limited availability of feed during droughts and poor marketing management. The low production rate of sheep and goats is a serious restriction to the rate at which the supply responds to increases in prices and costs and translates into low return on investment (Rumosa Gwaze and Dzama, 2009).

Most farmers rear their goats and sheep through the extensive system in range conditions without any supplementation. This system of production causes reduced growth rate and poor reproductive performance, thus resulting in severe economic loss. Kassam *et al*. (2009) argued that, the main constraint to increasing livestock productivity and output is lack of adequate supplies of good quality livestock feed in the dry season (produced at a competitive cost and without jeopardizing household food security). In addition, Masikati (2010) indicated that high incidence of diseases and mortality rates as well as feed shortages, lead to low livestock productivity. Gwaze *et al.* (2009) state that constraints to goat production include: diseases, prevalence of parasites, low levels of management, limited availability of forage and poor marketing strategies. This is true for the North West Province (South Africa) where the Tswana goat breed is mostly reared. The community rearing this breed is poor and cannot afford to undertake supplementary feeding schemes. One other constraint is the high mortality rate of kids, which stands at 40.6 % in rural areas due to theft and poor management (Webb and Mamabolo, 2004). Sometimes, farmers sell their goats among themselves (2009).

Water availability is another common constraint faced by farmers in semi-arid areas. In some areas, water may be available but insufficient to support healthy growth and performance of animals (Masikate 2010). Masikate (2010) also reported that water constraints were prevalent during the dry season, where animals had to walk distances of up to 14 km per day to access water. Water points are, sometimes, limited and large numbers of animals use the same points, thus leading to high chances of spreading diseases and land degradation (Masikati, 2010).

2.4 AVAILABILITY OF FEED

Mafikeng has an altitude of 1278 metres above sea level. It is a semi-arid environment with savannah type vegetation and summer rainfall averaging 540 mm per year (Bakunzi *et al*., 2012). It has one long dry season (winter), extending from November to February (Bakunzi *et al.*, 2012). The study area is characterised by a poor grazing land for which the management of rangelands, rangeland fires and droughts, limit the availability of feed in these areas (Ben Salem and Smith, 2008).The production of goats and other ruminants in this area is hindered by shortage of good quality feed, especially during the long dry season. To cover the

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shortage, supplementary feeding is regularly provided to farmers during winter; however, only a few farmers could afford (Masikate, 2010). In semi-arid areas, and particularly in communal areas of Mahikeng and surroundings, pastures are generally of poor quality and there is need, therefore, for supplementary feeding of small stock, especially during the dry season (winter). Bakunzi *et al*. (2012) observed that availability of low cost sources of protein (protein supplements) for use by communal farmer such as cotton seed cakes and ground nut husks, enhances the nutritional resources that could be provided to the animal, thus reducing the detrimental effects of gastrointestinal parasites on the animals, hence a substantial increase in productivity. Supplementing with molasses, soy beans and maize was noted to have an advantage to farmers (Bakunzi *et al*., 2012). In semi-arid areas, since goats are browsers, they control their encroachment by eating short grasses such as *Aristida species, Cenchrus species, Digitaria species and Acacia* trees and bushes (Bakunzi *et al.,* 2012).

2.5 CORRELATION BETWEEN FEEDING AND SERUM BIOCHEMICAL PARAMETERS

Growing awareness of the relationship between diet and health among consumers has increased demands for foods containing functional micro components that may help in maintaining health and preventing diseases (Scollen *et al.,* 2006). Oetzel (2008), indicated that analysis of biochemical blood parameter is an important metabolic profile test in goats and cows Researchers have strongly emphasised the significance of blood biochemical parameters such as total protein, serum albumin, serum globulin and urea, in the assessment of animal nutrition and health (Lali, 2009; Nozad *et al*., 2011). Damper *et al*. (2014) also state that the total protein, globulin, albumin and urea, function together to provide an indication of the protein status. Furthermore, Ndlovu *et al*. (2014) found that the physiological status of animals, season, age, breed and nutrition are factors that could affect the levels of blood metabolites. These concentrations could also vary with locations. There is, therefore, a need to evaluate the nutritional status of animals in goats in the North West Province.

2.6 BLOOD CHEMISTRY, GOATS' HEALTH AND PRODUCTIVITY

According to Gupta *et al.,* (2007), examining blood for their constituents is used to monitor and evaluate the health and nutritional status of animals. Furthermore, the physiological and pathological conditions of animals could be assessed by haematological and biological

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analyses of blood (Khan *et al.*, 2011). Sejian (2013) reported that the physiological response of goats to environmental stress during the dry and wet seasons, with their energy balance, revealed that seasonal heat and cold stress have effects on some thermoregulatory live body weight and physiological parameters. Sanusi *et al.* (2010) maintained that the best thermo-physiological parameters to objectively monitor in harsh environments are rectal temperature, respiratory rate and blood indices. In addition, Okoruwa (2014) confirmed that serum biochemical parameters were also affected in heat-stressed goats.

The most important role of glucose is to supply 60% of the energy demand of the animal (Okoruwa, 2014). The concentration of glucose in the blood normally, is regulated by hormone (insulin and glucagon); however, it is influenced by several other factors as well (Sakha *et al*., 2008). Urea provides a non-toxic means for excretion of ammonia generated by amino acid catabolism and the intestinal micro flora (Sakha *et al*., 2008). Urea production occurs almost exclusively in the liver, and failure is frequently associated with a decrease in urea (Sakha *et al*., 2008). According to Carlson (2002), some situations such as dehydration or renal failure may cause an increase in serum urea. The absolute muscle mass and level of physical activity could influence the concentration of serum creatinine (Carlson, 2002). In ruminants, creatinine is a more reliable indicator of alterations in renal function than urea (Smith, 2002).

Serum biochemical and haematological references constitute important panels in the diagnosis, prognosis and treatment of livestock diseases through investigation of myriads of parameters influencing blood and serum biochemical indices Notable indices are packed cell volume (PVC), mean corpuscular volume (MCV), total blood glucose (TBG), total protein (TP), urea, creatinine, uric acid, alanine aminotransferase or alanine transaminase (ALT), aspartate aminotransferase (AST), aminotransferase, alkaline phosphate (ALP), lactate dehydrogenase (LDH), creatinine kinase (CK), albumin (ALB), G-glutamyl trans peptidase (GGT), amylase, globulin, cholesterol, and very low density lipoprotein (VLDL), (Yokus *et al*., 2006). Parameters influencing the haematology and serum biochemistry of various livestock animals are typically classified under two broad categories as follows: genetic and non-genetic parameters. Genetic parameters include the heritability, repeatability and genetic relationships among traits while non-genetic parameters include the breed, age, sex, management system, medication status of the animal, (Menon *et al*., 2013). The haematological values of animals are also influenced by geographical location, season,

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climate, day length, time of the day, life habit of species, nutritional status, physiological status of individual animals and other non-genetic factors (Etim *et al*., 2014). Laboratory blood tests are vital tools to help detect any deviation from normal state of well-being of animals (Menon *et al*., 2013). Hence, it is important to establish standard values for the various blood parameters based on age and the other non-genetic parameters in Tswana goats.

2.6.1 Total protein (TP) and animal health

Kreplin and Yaremcio (2009) observed that proteins are the essential building blocks of most tissues and most animal feed rations and serve as the second limiting nutrient. First ovulation or oestrus may be influenced by excessive feeding of rumen degradable proteins. Total proteins increase due to dehydration, chronic inflammation and para-proteinaemia. It also decreases due to haemorrhages, burns, dietary protein deficiency and some viral conditions (Merck Veterinary Manual, 2010).

2.6.2 Lipase and animal health

Afonso *et al*. (1999), reported that lipase are subclasses of enzymes involved in hydrolysis of ester compounds in the cell. Girod (2002) reported that lipase in living organisms plays important roles in processing, transporting and digestion of dietary lipids through its involvement in a number of biological processes, including metabolism of triglycerides in diet and cell signalling (Spiegel *et al.,* 2000). Hamilton (2013), highlighted that high levels of lipase in blood, referred to as hyperlipasemia, could result from pancreatitis, increased tumours of the pancreas, gallbladder infection and kidney failure.

2.6.3 Cholesterol and animal health

Cholesterol is a lipid or fat structure which circulates in the blood stream and is also important for life (Guzel and Tanriverdi, 2014). Furthermore, Damptey *et al.* (2014) state that cholesterol is a type of fat or lipid found in all cells of the body. Tena-Sempere (2012) maintain that for ovulation to occur, cholesterol, which is a precursor of the steroidal hormones, plays a fundamental role in the steroid pathway, which is required to promote follicular growth and development at the ovarian level.

The risk of reproductive disorders, diabetes mellitus and cardiovascular diseases due to obesity (from increased cholesterol levels), are twice higher in animals (Ahmad *et al*., 2004).

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Cholesterol has also been reported to increase due to fatty meals, hepatic or biliary diseases disease and hypothyroidism; however, it may decrease during severe cases of liver dysfunction (Merck Veterinary Manual, 2010). Cholesterol levels may decrease with the stage of lactation. Conversely, high dietary cholesterol levels are highly influential in the occurrence of cardiovascular diseases (Faye *et al.*, 2015).

2.6.4 Urea and animal health

Blood urea nitrogen has been defined as a small molecule that equilibrates between plasma and the reproductive tract. (Canfield, 2000). Moreover, blood urea nitrogen plus creatinine concentration, aid as a good indicator of protein metabolism and both play a critical role in the functioning of the kidney (Damptey et al., 2014). Greenwood *et al*. (2002) reported that during dry periods, energy requirements in the body could be replaced by the process of protein catabolism, which results in increased urea concentrations in the blood. Magnus and Lali (2009) reported that low serum urea nitrogen may be seen in animals with post-partum metritis.

2.7 NUTRITIONAL REQUIREMENT OF GOATS

2.7.1 Energy requirements in goats

Saeed *et al*. (2012) conducted a study on the effects of different dietary energy levels on the growth performance of Kamori goat kids. No significant difference was observed between net revenue from control and kids fed with high energy (HE) 2.56 MCal/kg whereas, net loss in revenue was observed in goats fed on low energy rations. It was, therefore, concluded that high energy ration feeding could be beneficial for goat production. Saeed Ahmed Abbasi *et al*. (2012) reported that fertility could be impaired by drought, poor pastures, change to lower quality feedstuffs, conditions which produce lower feed intake, high production (of offspring or milk), which exceed energy supplies and plain underfeeding. An increase in energy supply is often followed by improved rates of ovulation and conception (Smith and Chase, 2010). Rumosa Gwaze *et al*. (2009) reported that lack of energy supplied below the required, decrease level of maintenance plus pregnancy, and affects the survival of kids, the level of milk production and length of lactation. Hence, energy supply has a marked effect on age of puberty and thus, on the age of first kidding. Rumosa Gwaze *et al*. (2009) maintained that early breeding to reduce cost of replacements requires sufficient size of doelings rations. Hale

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and Olson (2005), reported that, inadequate size of doelings at breeding may be followed by kidding problems five months later and excess energy may also be detrimental physiologically by producing heavier doelings and reducing conception rate. Michalek *et al*. (2008) noted that goats need extra energy not only for their pregnancy, but also to continue their growth rate sufficiently. Furthermore, shortage of energy in goats, especially under range conditions, is known to cause not only stunted growth but also abortion in goats. This occurs mostly between 90 and 110 days of gestation when under-nutrition is especially critical to normal foetal development. The so-called stress abortion is triggered by low maternal blood glucose levels, which cause hyperactivity of the foetal adrenal gland (Michalek *et al*., 2008). In addition, it was observed that maternal hyperadrenalism could also stem from under-nutrition and low blood glucose, thus resulting in dead or autolyzed foetus. Michalek *et al*. (2008) found that abortion can often be prevented by sufficient nutrition since many fertility problems could be considered a temporary reaction to a negative energy balance.

2.7.2 Protein requirements in goats

Goats provide food and fibre to many people in the world, as well as imparting other social and economic benefits. However, very little is known about the nutrient requirements of goats compared to cattle and sheep (Bengaly *et al*., 2007). Masika *et al.* (2010), in a comparison between commercial and communal goats reared in the Northern Cape Province, found that nutrition could be a factor in growth performance since available herbage on the veld is of low crude protein content, low digestibility and at a mature stage of growth. Herbage in the communal system was found to be of higher crude protein content and digestibility, at an actively growing stage, probably due to irrigations. Wattle tannin extracts, when given as a dietary supplement, did not improve the protein status and, therefore, growth performance of goats (Bengaly *et al*., 2007).

Bengaly *et al*. (2007) argue that protein is required for most normal functions of the body, including maintenance, growth, reproduction, lactation and hair production. Protein deficiencies in the diet stores in the blood, liver and muscles, predispose animals to a variety of serious and even fatal ailments. Most forages contain adequate amounts of dietary protein for maintenance; however, lactating, growing, sick, or debilitated animals may require diets fortified with legumes or protein supplements (e.g., soybean meal and cottonseed). Feeding

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adequate to slightly greater amounts of protein than required, appears to aid in the control of internal nematode parasites (Bengaly *et al*. 2007).

Furthermore, even when energy supplies are adequate, shortage of protein will impair fertility, cause delayed onset of puberty, and lengthen oestrus or result in weak expression of oestrus if it occurs. Hence, excessive protein is not only an economic waste but feeding is costly and could lead to posthitis or sheath rot in male goats, especially those in confinement (Bengaly et al. 2007). Oyeyemi and Akusu (2002) found that inadequate levels of protein in the diet could negatively affect growth rate, milk production, reproduction and disease resistance since insufficient amino acids are getting to the intestines to be absorbed by the body. Unlike energy, excess protein is not stored in the body of the goat; it is excreted in the urine as urea. Thus, it is important for animals to have access to enough protein to cover their nutritional requirements (Oyeyemi and Akusu, 2002). Nagvi *et al*. (2013) reported that proteins are organic compounds that contain carbon, hydrogen, oxygen, and nitrogen sometimes iron, phosphorus and sulphur. Nagvi *et al*. (2013) further reported that proteins are needed to grow new tissues and to repair old ones in an animal. Every day, 3 to 5% of the body's proteins are built. Furthermore, the highest amounts of proteins can be found in muscles (Nagvi *et al*. 2013)

According to Alam *et al*. (2011), the most common nutrient deficiency is protein. Since most feedstuffs are low in proteins, protein supplements may be necessary. Young animals need diets higher in proteins than older animals since they are needed to grow new tissues and to repair old ones in an animal. Alam *et al*. (2011) found that animals in gestation or lactation also need higher levels of proteins in their diets. Proteins are made up of various combinations of up to 26 amino acids. Amino acids are building blocks of proteins. Amino acids are classified as either essential or non-essential (Alam *et al*. 2011). Ocak *et al*. (2009) moot that most ruminant animals can synthesise non-essential amino acids. Monogastric animals are unable to synthesise amino acids and thus, should have their diets supplemented with proteins containing the 10 essential amino acids. Ruminants are capable of synthesising all amino acids by microbial action in the rumen (Ocak *et al*., 2009).

2.8 Mineral requirements in goats

Minerals are inorganic elements found in small amounts in the body and recent research has shown that minerals nutrition has an important role in the performance of goats, and the

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relationship between nutrition and physiology has played a key role in recent years (Arguëllo, 2011). Bakunzi *et al*. (2012) posit that some farmers may have to supplement phosphorus during winter since this is when the pasture is so dry, while others may also supplement in summer. Semi-arid areas might have some mineral deficiencies and to prevent mineral deficiencies, minerals are included in livestock feed rations and provided through free access to mineral and salt blocks (Alam *et al.,* 2011). Furthermore, Marley *et al.,* (2005) observedthat effects of food supply and possibly, of parasitic status, are especially marked on analyses that reflect energy and mineral metabolites levels of animals. Mineral deficiencies could lead to poor weight gain, poor feed efficiency and poor reproductive traits (Alam *et al*., 2011). Minerals are classified as macro or micro (Ocak *et al*., 2009).

2.8.1 Macro mineral requirements

Mamoon (2008) argues that macro minerals are those needed in the diet in relatively large amounts. Requirements could range from a few tenths of a gram to one or more grams per day. Mamoon further maintains that macro minerals include calcium, chlorine, magnesium, phosphorus, potassium, sodium and sulphur. Mamoon (2008) highlighted that calcium and phosphorus are needed in a certain ratio for bone growth and repair and for other body functions. Magnesium is needed for chemical reactions in the muscles and for skeletal growth (Mamoon, 2008). Grass tetany, a potentially deadly condition that occurs in lactating cows on spring pastures, is a result of magnesium deficiency. Potassium aids in the uptake of glucose.

2.8.2 Micro minerals

Ocak *et al*. (2009) reported that micro minerals, or trace minerals, are those required in small quantities. Such minerals are just as important as macro minerals and are needed in smaller amounts. Requirements could range from a millionth of a gram to a thousandth of a gram per day as described by Mamoon (2008) (Table 2.1). He noted that Micro minerals include chromium, cobalt, copper, fluorine, iodine, iron, manganese, molybdenum, selenium and zinc. Chromium activates certain enzymes involved in the production of energy. Cobalt is a part of the molecule of vitamin B12. Copper is necessary for normal iron absorption (Mamoon, 2008). Fluorine promotes sound bones and teeth. Iodine is needed by the thyroid gland in the synthesis of thyroxine. Iron is required for the production of haemoglobin, a protein in the red blood cells that transports oxygen to tissues and carbon dioxide from tissues. Manganese plays an important part in the formation of bones and in blood clotting.

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Molybdenum serves many purposes and is part of tooth enamel. Selenium, along with vitamin E, helps prevent white muscle disease. White muscle disease is a potential condition in young calves as a result of selenium deficiency. Zinc, in proper amounts, has a major effect on bones, skin, hair and feathers (Mamoon, 2008).

Table 2.1: Acceptance of quantities of macro and micro minerals in a goat's diet (Mamoon, 2008)

Macro minerals	(%)	Micro minerals	(ppm)
Calcium	0.3- 0.8	Iron	50-1000
Phosphorus	0.25 -0.4	Copper	10-80
Sodium	0.2	Cobalt	0.1-10
Potassium	0.8-2.0	Zinc	40-500
Chloride	0.2	Manganese	0.1-3.0
Sulphur	0.2-0.32	Selenium	0.1-3.0
Magnesium	0.18-0.4	Molybdate	0.1-3.0
		Iodine	0.5-50

2.8.3 Minerals and reproduction

Bakunzi *et al.* (2012), in South Africa, reported that phosphorus has been recognised as a nutrient, which is a major production constraint in ruminants in several parts of semi-arid communal areas and osteomalacia, presented as stiffness, could be clinically observed due to insufficiency of P in the diet. Suttle (2010) highlighted that calcium is the most abundant mineral in the body and 99% is found in the skeleton. However, a small proportion of the body calcium that lies outside the skeleton, is important for survival. Magnesium is the second most abundant intracellular divalent cation (Blaine *et al*., 2014).

2.8.4 Importance of minerals in goats

The health and reproductive performance of grazing livestock depends on the adequacy and availability of both essential macro and micro elements from pastures.

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Additional studies have shown that ruminants require a number of dietary mineral elements for normal body maintenance, growth and reproduction. Phosphorus, Ca and Mg are among the major minerals required in relatively large amounts for body maintenance, growth and reproduction (Hale and Olson, 2001). The most common problem associated with Mg deficiency, also known as grass tetany, is observed most frequently in early spring and results from the consumption of lush forage, which has low levels of Mg. Calcium (Ca) is considered an important mineral used in the formation and maintenance of bones and teeth. Due to its importance in bone structure, deficiency of this mineral in young animals leads to skeletal deformities, and also functions in the transmission of nerve impulses and contraction of muscle tissues. Read *et al.* (1986) found that South African pastures cannot supply adequate phosphorus. Selenium is a non- metal with similar chemical properties as sulphur. It is a crucial ingredient of the glutathione enzyme system. In ruminants, the need for selenium is generally low (Read *et al*., 1986). However, forage and different feedstuffs produced in some parts of the world, lack selenium. Selenium supplementation is required in these regions to anticipate economic losses in animal production (Nawito *et al*., 2015). Extensive research indicates that selenium and vitamin E play an important and crucial role in shielding the body from diseases (Wilkins and Kligour, 1982). Furthermore, Boland (2003), demonstrated that supplementation with selenium and vitamin E diminishes the frequency of retained placenta, metritis and increase the rate of uterine involution.

Selenium is necessary for growth and fertility in animals and also for the prevention of a variety of disease conditions, which show a variable response to vitamin E for reasons which are becoming clearer considering the fact that there is a lot of information about the functional forms of selenium and their localisation (Macpherson, 1994). Selenium also protects the body of animals from heavy metals by forming complexes to render them harmless (Kachuee *et al*., 2013). According Kachuee *et al*. (2013), selenium is easily transferred through the placenta and milk; therefore, the selenium status of does directly affects the health and thriftiness of kids. Zinc is necessary in the production of more than 70 enzymes in the body of animals (Nawito *et al*., 2015). Some of these enzymes are: phytases; carbohydrases; and proteases, among others. Due to its contribution in such a large number of catalysts, zinc is basic for vitality and protein digestion (Nawito *et al*., 2015).

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2.8.5 Mineral deficiency in goats

Selenium deficiency could make cells to be susceptible to oxidation (Nawito *et al*., 2015). Nix (2002) states that marginal selenium deficiencies could result in impaired fertility, silent heats, cystic ovaries and the birth of unthrifty kids with poor immunity. Limited zinc intake during pregnancy, has serious impacts in animals, leading to foetus loss or premature labour (Kachuee *et al*., 2013). According to Nawito *et al*. (2015), serious zinc deficiency is uncommon in practice; however, borderline zinc deficiency is more frequent in ruminants.

2.9 DISEASES AND PARASITES

According to the Department of Agriculture, Forestry and Fisheries (2012), the most prevalent health problems associated with goats in the North West Province are as follows: pneumonia; and internal parasites. The major constraints to the production of goats in the Province are: high deficiency such as hypo magnesium; hypocalcium in goats during late pregnancy associated with rapid calcium loss to the developing foetus for bone mineralisation; prevalence of parasites; low levels of management; poor marketing; heart water; mineral deficiencies and high abortion rates (Mutibvu *et al*., 2012). Eighty percent of farms in this region do not reserve particular pastures for goats, and they are not herded but allowed to roam freely. It was also concluded in a study conducted by DAFF in South Africa that commercial production of goats marketed at an optimum age, could potentially improve the economy of small farmers in the North West Province of South Africa (Department of Agriculture, Forestry and Fisheries, 2012). High rate of abortions usually occurs due to underfeeding, especially due to lack of trace minerals (Ndou *et al*., 2013). This tends to lower economic benefits since production is very low. Simela and Merkel (2008) observed that 88% of farmers considered most of their goats to give birth only once a year, 56% of farmers reported that kidding occurred once or twice a year at an equal frequency in their flocks. Twins were more commonly reported in sheep than goats (Simela and Merkel, 2008). According to the same study, mating was usually uncontrolled and led to inbreeding. This probably was common as the progeny of the most active breeding ram or buck was often the main source of replacement males. Breeding rams and bucks were found in 50% and 25% of the flock while other flock relied on animals being bred during the non-cropping season, when most of the stock were on free range (Simela and Merkel, 2008).

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2.10 MARKETING INFRASTRUCTURE

Live goats reared by commercial farmers are sold at better prices in the informal market, thus explaining why producers prefer to supply the local demand before thinking of the export market (Department of Agriculture and Forestry, 2012). According to Randolph *et al*. (2009), livestock keeping of rural communities reflects the constraints they face (e.g. finance, access to information and service as well as the reasons why they keep livestock). In South Africa, slaughtering of livestock for meat in rural communities is infrequent and done only when animals are sick or old, or when required for cultural ceremonies and hospitality (Meissner *et al.,* 2013). Malher *et al.* (2001) observed that female fertility is a key functional trait since it is one of the main reasons for involuntary culling in small ruminants. Furthermore, Alelovich *et al*. (2011) state that owners of goats may produce for the market; however, sales are usually occasional in order to meet urgent needs for cash. Meissner *et al*. (2013) concur with the above finding and maintain that communal farmers sell their livestock for urgent cash, as a form of insurance, or to provide for the family when the owner dies. Seleka (2001) noted lack of organised marketing of goats in Botswana / South Africa. Communal farmers resort to informal ways of marketing their goats, where pricing is based on an arbitrary scale, with reference to visual assessment of the animals.

According to Okello and Obwolo (1984), where goats are sold in large numbers, the money could be used for big investments such as the building of shops and residential houses. However, according to Simela and Merkel (2008), farmers purchase live animals among themselves in order to resell in other areas such as towns. All these transactions are not captured in official statistics thus, leading to underestimation of production and consumption to chevon in Africa.

2.11 NUTRITION AND THE PRODUCTIVITY OF GOATS

2.11.1 Mineral nutrition

Goats as all production animal require a specific dietary and mineral content in their daily diet (Table2.2). Animals require considerable amount of protein since their bodies and products (meat, milk) are composed of high levels of protein. Most common feeds are low in protein, and supplying proteins to livestock is a major challenge. Since most feedstuffs are low in proteins, protein is the most common deficient and costly nutrient supplement (Lodish et al., 2004). According to Dobson (2000), symptoms of protein deficiency include anorexia,

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slow growth rate, decrease feed efficiency, low birth rate and lower milk production. Mineral requirements for goats vary from one area to another, depending on the soil composition. Mokolopi and Beighle (2006) (in a study on the mineral composition of goats in different matrices) found a decline in the mineral content of animal faeces with the worsening of grazing during the winter season. Furthermore, the same study noted that values for body mass and conditional scores of experiment animals used, declined during the dry season. It was widely acknowledged in the study that poor reproductive and growth performance of grazing animals could specifically be attributed to low protein, imbalance of phosphorus, calcium and other minerals in forage (El-Shahat and Abdel Monem, 2011).

Ndlovu (2012) states that goats get higher amounts of minerals because they consume more browse than sheep, while Bengaly *et al*. (2007) found that phosphorus deficiency is more likely than calcium deficiency in grazing goats (largely due to phosphorus deficient forages). The authors also observed that a level of 0.4 % P in the total ration was recommended. The ratio of calcium to phosphorus should not be much different from 1.2:1.0 as excess dietary phosphorus has been associated with the occurrence of urinary calculi, particularly in confined bucks. In such cases, a Ca: P ratio of 1.5:1.0 or greater is recommended (Bengaly *et al*., 2007). According to Christophe (1998), reproductive problems such as low first service conception rates and silent heats have been related to wide Ca: P ratios and to phosphorus deficiencies, while vitamin D has also been implicated through its effect on phosphorus utilisation. Christopher (1998) also confirmed that vitamin D supplementation is advised for young, poorly growing kids, goats in confinement and those exposed to little sunlight. Marcy (2005) reported that goats require a lot of minerals for basic body function and optimal production.

Major minerals likely to be deficient in the diet are calcium, phosphorous and magnesium (Marcy, 2005). Low quality, mature or weathered forages could be deficient in phosphorous, especially for lactating does (Marcy, 2005). The ratio of calcium to phosphorous in the diet is important and should be kept 2:1, which should be a consideration when using feeds that are high in phosphorus and low in calcium (like wheat middling, corn, or corn gluten feed) (Cohen, 1975). According to the Department of Agriculture, Forestry and Fishers (2012), proper balanced nutrition can affect the reproductive soundness of the herd. Protein and energy are important in conditioning the doe and buck, while vitamins and mineral supplementation could address healthy eggs and sperm (Department of Agriculture, Forestry

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and Fisheries, 2012). Results obtained from different studies have concluded that more research is needed on goats to evaluate whether proteins, energy and minerals could improve reproductive health and performance on small stock (Department of Agriculture, Forestry and Fisheries, 2012).

2.11.2 Effects of diets / nutrition and management systems on serum biochemistry

Maurya *et al*. (2010) state that nutrition plays a key role in regulating reproductive performance in farm animals. According to Swanson *et al*., (2004), serum vitamin, protein and lipid concentrations are affected by diet/nutrition. Lack of adequate year-round feed resources is probably an important factor that contributes to low animal production in semi-arid regions in the world (Ben Salem and Smith, 2008; Kawas *et al*., 2010). For instance, trace element cobalt has been found to play a very significant role in the biosynthesis of vitamin B12 in livestock animals (Maurya *et al*., 2010). In addition, deficiency of cobalt in animal feeds could lead to vitamin B12 deficiencies-related diseases (for example, liver-related diseases referred to as hepatic lipidosis) (Menon *et al*., 2013).

Animal management has also showed that it might have an impact on the animal blood's and biochemical parameters (Menon *et al*., 2013). Glolabo *et al*. (2015) established that animals reared under extensive systems, tend to have lower glucose levels compared to those reared under intensive systems. The authors concluded that the sedentary nature of animals under intensive care may probably cause an increase in the levels of blood glucose while animals under extensive care might have consumed appreciable levels of their blood glucose for physical and ranging activities (Menon *et al*., 2013). Thus, the management system under which animals are kept, greatly affects a wide range of haematological and serum biochemical parameters (Glolabo *et al*., 2015).

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Table 2.2 Nutritional requirement for goats

Nutrient requirements for mature does

Production stage	**Nutrient requirements, dry matter basis**		
	DMI% of BW	**% CP**	**%TDN**
Maintenance	1.8-2.4	7	53
Early gestation	2.4-3.0	9 -10	53
Late gestation	2.4-3.0	13 -14	53
Lactation	2.8-4.6	12 - 17	53 - 66

Nutrient requirements for selected groups of growing kids

Production stage			**Nutrient requirements, dry matter basis**
	DMI,% of BW	**%CP**	**% TDN**
25 kg dairy doelings and castrates, gaining 100 150 g/hd/day	3.3-3.8	12	67
25 kg boer doelings and castrates, gaining 100-150 g/hd/day	3 - 3.4	15 -17	67
25 kg intact dairy males, gaining 100 g/h/day-150 g/hd/day	3.2 - 3.7	10 15	67 86
25 kg intact boer males, gaining 100-150 g/hd/day	3.3 – 3.7	15	67

Actual requirements will vary depending on breed, productivity and environment. DMI- dry matter intake, BW- body weight, CP- crude protein, TDN- total digestible nutrients

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2.12 PRODUCTION AND MANAGEMENT OF GOATS

According to Smith (2008), indigenous goats are valuable reservoirs of genes for adaptive and economic traits in providing diversified genetic pool, which could assist in meeting future challenges resulting from possible changes in production systems and consumer requirements (Kosgey and Okeyo, 2007). Goats are the principal ruminants in many scrublands and are part of traditional extensive grazing systems in many countries (Alexandre and Mandonnet, 2005). Goat production in villages, following the traditional husbandry system, is often characterised by poor growth rates, high mortality and low reproductive rates (Kabir *et al*., 2004). According to these authors, productivity of goats could be increased by controlling diseases through vaccination and anthelmintic drugs and improving nutrition by either concentrate feeding or supplying additional forage. The aim of pre- partum feeding is to obtain higher birth weights, lower kid mortality and higher growth rate of kids (Sahu *et al*., 2012). The authors further argue that maintenance of good health of does ensures good supply and pre-weaning period.

Olafadehan (2011) argues that in various parts of the world, particularly where animals are raised by natural range grazing in the tropics, it is customary to use non-conventional feeds such as browse legumes as a supplement to poor quality and inadequate grasses, especially during the dry season. This is largely because they are capable of yielding high protein forage during critical mineral deficient periods, especially during the dry season (Sahu *et al*., 2012). The improvement of the productivity and marketing of goats requires a good understanding of the characteristics of goat production systems (Assan and Sibanda, 2014). Supplemental food to does during late pregnancy has proved to reduce kid mortality by improving birth weight and enhancing the immune system, while reducing the incidence of hypothermia (Mahboub *et al*., 2013). According to Waziri *et al*. (2010), management practices, such as feeding, health condition and productivity could influence biochemical indices such as glucose, urea, total protein and creatinine levels. Physiological blood serum specific chemical reference parameters and their variation should be established in purebred and cross-bred dairy female goats under intensive farming systems (Mohammed *et al*., 2016).

Goat meat production from the veld is far less important than commercially produced beef or mutton. Nevertheless, goat production is gaining importance, perhaps due to the higher demand by rural consumers and the increase in small-scale subsistence farming systems in South Africa (Almedia and Schwalbach, 2006). The need to improve productivity of Tswana

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goats is because these animals are likely to increase the incomes of smallholders and household nutrition (Madibela and Segwagwe, 2008). It has been concluded that goats will continue to have an important role in harsh conditions as well as tropical, subtropical, desert and Mediterranean environments (Silanikove and Koluman, 2015). It is well documented that nutritional supplementation influences the reproductive performance of goats (De Santiago-Miramontes *et al*., 2009).

The aim of pre-partum feeding is to increase birth weights, lower kid mortality and higher growth rate of kids (Ashworth *et al*., 2009). Maintenance of good health of does ensures good supply of nutrients to kids, both during pregnancy and the pre-weaning period (Sahu *et al.*, 2013). Nutrition has a significant impact on numerous reproductive functions, including hormone production, fertilization and early embryonic development (Grazul-Bilska *et al*., 2006).

2.13 SUMMARY

This chapter focussed on the qualities of the Tswana goat breed and their use by communities breeding them. Major constraints to goat production in the North West Province include diseases such as hypo magnesium, hypo calcium in goats during late pregnancy associated with rapid calcium loss to the developing foetus for bone mineralisation, prevalence of parasites, low levels of management, poor marketing management, heart water, mineral deficiencies, and abortion. The study area is characterised by an acute shortage of feed supply during the dry season and the available feed during this period is usually of very poor quality (low in protein and high in fibre content), which results in low digestibility and low voluntary intake by animals. Seasonal shortage of forage on small farms in the North West Province is considered a constraint to goat production due to small farm sizes and overstocking of livestock.

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CHAPTER THREE: PRODUCTION SYSTEMS, MANAGEMENT AND MARKETING STRATEGIES OF TSWANA GOATS IN SEMI ARID AREAS AROUND MAFIKENG, NORTH WEST PROVINCE, SOUTH AFRICA

3.1 ABSTRACT

Goat production in communal areas faces several challenges, which may differ with geographical locations. Marketing of goats in the North West Province is likely to diversify the economy and alleviate poverty in rural communities. Only 75 farmers (out of 150 targeted) had goats in Ramatlabama 600, Tsetse and Lokaleng villages. Farmers were randomly chosen to participate in the study and a structured questionnaire was used to collect data. The survey was based on the production systems, management and marketing strategies of Tswana goats in semi- arid areas around Mafikeng, North West Province, South Africa. The results obtained showed that 57% (n =75) of farmers sold animals without weighing them and were also affected by the weak market value of livestock. About 29% of farmers reported cases of abortion in the production process, largely due to droughts and mineral deficiencies, Other factors include poor housing and low soil fertility for forage production. In addition, major constraints to goat production included the following: stock theft (45%); malnutrition (33%); and diseases (32%). A significant correlation ($P<0.005$) was observed between grazing system and access to veterinary services. The major constraints limiting goat production in communal areas included uncontrolled breeding, theft and diseases. Issues raised by farmers should be considered in designing and implementing effective breeding programmes for goats to improve their overall productivity and contribution to poverty alleviation in these communities. There is need to educate rural farmers on management and marketing of goats within the study area. This will make significant contribution in addressing the problem of goat management.

Keywords: Goats, production, management and marketing

3.2 INTRODUCTION

Goat production and productivity in communal areas faces several challenges, which could differ with areas, countries, regions or geographical locations (Masikate 2010). There are nearly 750 000 goats in the North West Province, representing about 11% of the total goat population in South Africa. Of this number, close to 13% are Boer goats and the remainder

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consists of a variety of indigenous goats (Bakunzi *et al*., 2012). While goat production in the Province has remained fairly stable over the last 15 years, exports of live goats and goat meat from the Province have remained remarkably low (Bakunzi *et al*., 2012).

Goat production could be divided into commercial and rural. Mortality and morbidity losses due to diseases in goats have been a major constraint in traditional flocks (Kumar *et al*. 2003). Losses due to diseases suffered by goats on commercial farms have been estimated. The major diseases that affect goats on commercial farms are as follows: enterotoxaemia; pox and foot and mouth disease. Other health ailments include abortion and external parasites in rural areas (Kumar *et al*., 2003). Mortality rates are largely due to poor hygiene, management and feeding (Masikate, 2010). Mating is not controlled and occurs all year round, thus, creating managerial problems. Livestock production is often carried out under unstable and hazardous production conditions and further threatened by bush encroachment (Bakunzi *et al*, 2012). It was concluded that initiatives aimed at improving the economic, nutritional and health status of this community, through increased goat production, are unlikely to be successful and that the problem of bush encroachment is likely to increase to the detriment of other ruminant species in future (Masikate, 2010). Common challenges faced by goat farmers are mostly feed shortage, mortality of kids, lack of veterinary services and difficulties to integrate into the commercial market (Masikate, 2010). According to Kassam (2009), the main constraint to increasing livestock productivity and output is lack of adequate supplies of good quality livestock feed produced at a competitive cost and without jeopardizing household food security, particularly in the dry season. Major constraints increased incidences of diseases and mortality rates, feed shortages, unavailability of water mainly during the dry season, and poor veterinary support (Masikati, 2010). Water points are, sometimes, limited and several animals use the same points thus, leading to high chances of spreading diseases (Masikati, 2010). Peeling and Holden (2004) pointed out that the failure of government services to provide veterinary services, low fertility for forage production and weak market chains for livestock and livestock products are some of the issues affecting animal productivity in rural areas. These constraints are, however, within farmers ‘capacity to mitigate’ (Masikate, 2010). There is a negative perception that goat meat is of low quality (Masikate, 2010). This may be quite the opposite as to date, no information has been generated among goat farmers in Mafikeng.Hence, the purpose of this study was to examine the general demographic, social and economic characteristics of goat famers and challenges

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and constraints faced by such farmers to propose possible solutions to improve and expand activities.

3.3 MATERIALS AND METHODS

3.3.1 Study site

The study was conducted in Ramatlabama 600, Tsetse and Lokaleng villages in the Molopo District, Mafikeng area (25°5'S and 25º38´) of the North West Province, South Africa (Figure 3.1 below). Mafikeng has an altitude of 1278 m above sea level. The climate is semi-arid, with savannah type vegetation and summer rainfall, averaging 540 mm year, characterised by one long dry season (winter), extending from May to October, and a relatively short wet season (summer), extending from November to February (Bakunzi *et al*., 2012).

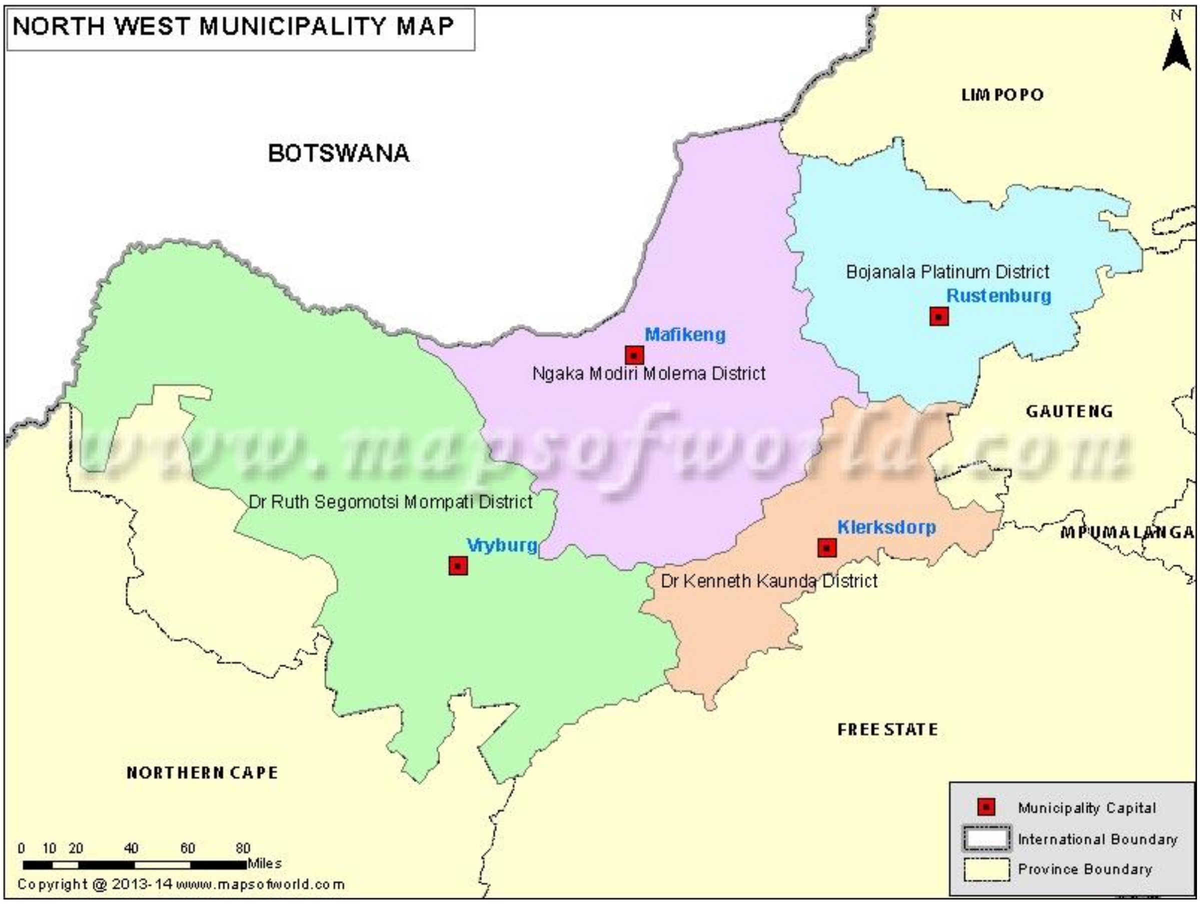

Figure 3.1: Map of Mafikeng Local Municipality, Ngaka Modiri Molema District of the North West Province (Source: Google Maps)

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3.3.2 Study population

The study population consisted of smallholder livestock farmers living in the three villages. A snowball sampling technique was used to collect data from goat farmers in the three villages that participated in the study. 75 goat farmers) were interviewed in this study. Upon the selection of the household, farmers were notified of the intended survey verbally. Each household was then visited and the purpose of the study was explained to farmers. Local Chiefs were informed of the study before the interviews.

3.3.3 Data collection

A questionnaire (see Annexure 1) was used to collect data for the study. The questionnaire requested information on the socio- economic profiles of farmers, animal productivity, nutrient supplementation practices, prevalence of diseases, farming constraints, goat utilisation, commercialisation and marketing strategies (Table 3.1). The questionnaire was completed in the presence of the head of the household. Questions were asked in English and translated into Setswana in situations where respondents had limited knowledge of English.

Table 3.1: Summary of the layout of the questionnaire used in the study

Part	Section	Items
1	A	-Location of farm, details of farmers
		-Household information
		-Livestock management
2	A	-Livestock activity
		-Production challenges
		-Diseases and control

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3.4 STATISTICAL ANALYSIS

Descriptive statistics were generated using the Statistical Package for Social Sciences (SPSS) (version 23 of 2016). The characteristics of heads of households and animal husbandry practices were identified as independent variables while size of herd, family income and livestock income were used as the dependent variables. The effect of independent variables on the size of herd, family income and livestock income was analysed using a one-way of variance (ANOVA) procedure of the Statistical Package for the Social Sciences (SPSS) version 23. Nominal relationships were analysed using Pear's chi-square test. The strength of the association was interpreted using Cramer's V coefficient.

3.5 RESULTS

3.5.1 Characteristics of respondents

The study was conducted in Ramatlabama Six hundred (14 respondents), Tsetse (20 respondents) and Lokaleng (41 respondents). Out of the one hundred and fifty questionnaires issued out, a total of 75 were completed and returned, thus representing a response rate of fifty (50) percent.

3.5.2 Demographic characteristics of goat farmers

Different age groups were interviewed in the study. Farmers aged between 31 and 70 kept goats in the study area. Results obtained in this study are shown in Table 3.2. Lokaleng villages were more actively involved in the rearing of goats. In Tsetse village, farmers who kept goats and were aged 41 and 50, formed 35.0% of the respondents, while in Lokaleng village, more farmers (43.9%) involved in the rearing of goats were aged 70 years and above. Most livestock owners were males, representing 57%.

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Table 3.2: Frequency distribution (%) according to age of respondents

Age	Ramatlabama 600 (n=14)	Tsetse (n=20)	Lokaleng (n=41)
31-40 years	17.1	10.0	4.9
41-50 years	35.7	35.0	12.2
51-60 years	14.3	10.0	14.6
61-70 years	14.3	15.0	24.4
More than 70 yrs	35.0	30.0	43.9

Majority of goat farmers (47%) in the three villages had completed elementary education, 32% had attended school up to standard ten (completed high school), 21% had attended school up to tertiary level while 12% had never attended school (Table 3.3). Only 25% of respondents owned land, 12% rented land while the remaining used communal lands for their farming. The study also revealed that farmers did not rely on farming for maintenance. It was further shown that among farmers who participated in the study, particularly those with an income scale of between 0-10 000 rands, 58% of such farmers were pensioners and received monthly grants from government while 25% of farmers were working. However, both categories of farmers were earning between R 0-10 000 as total annual income. Only 58% of income earned by farmers were generated from livestock annually.

The results also noted that 47% of farmers had livestock as their major activity on the farm, while only 16% did not consider livestock as their primary source of income. It was further shown that most farmers (68%) kept Tswana goats, 23% of farmers kept indigenous goats, while 21% reared the mixed breed of goats (Table 3.4).

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Table 3.3: Frequency distribution (%) according to level of education of respondents

Level of education	Ramatlabama 600	Tsetse	Lokaleng
Tertiary education	14.3	20.0	2.4
Completed high school	35.7	30.0	31.7
Completed primary school	48.0	35.0	51.2
No education	2.0	15.0	14.6

Table 3.4: Frequency distribution (%) according to breed of goats reared/owned.

Goat breed	Ramatlabama 600	Tsetse	Lokaleng
Tswana	64.3	0.00	70.7
Indigenous	28.6	65.0	14.6
Mixed	7.1	35.0	14.6

3.5.3 Livestock husbandry practices

About Sixty per cent (60%) of farmers in the three villages sampled for the study allow their goats to browse during the day, 25% of farmers practise free range/backyard farming while 15% practise semi-intensive farming and do not provide supplements to their animals but allow them to browse during the day (Table 3.5). It was found that during winter, about 71% of farmers use crop residues to feed their goats, 49% use concentrates as supplements for their goats while 67% of farmers supplement their goats with minerals. Of all the farmers

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visited in the study area, 83% indicated that they do not hire shepherd to look after their goats while 69% practised the free grazing system. It was also noted that 89% of goat owners kept their goats in a kraal, 17% kept their goats in their stall, while 29% of farmers kept their goats in the yard at night (Table 3.6). It was further revealed that 56% of goat owners allowed their animals to drink water at the river, 41% of farmers fetch water from the river for their animals while 3% of farmers provide water for their animals in their yards/farms (Table 3.7).

Table 3.5 Frequency distribution according to systems of production used by respondents

System of production	Ramatlabama 600	Tsetse	Lokaleng
Semi-intensive	7.1	0	0
Free range/backyard	71.4	20.0	12.2
Other	21.4	80.0	87.8

Table 3.6 Frequency distribution according to type of housing used for goats in the study area

Housing	Ramatlabama 600	Tsetse	Lokaleng
Kraal	64.3	90.0	94.0
Stall	21.4	5.0	3.0
Yard	14.3	5.0	3.0

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Table 3.7: Frequency distribution (%) according to water sources for goats in the three villages

Water source	Ramatlabama 600	Tsetse	Lokaleng
Animals go to water source	57.1	90.0	56.1
Water fetched/provided	14.3	5.0	0.0
Both	28.6	5.0	43.9

The study revealed that 74% of farmers in the three villages sampled had access to veterinary services.

3.5.4 Prevalence and control of diseases

Diseases among goats were reported as a main constraint to production in the three villages sampled. Heart-water was found to be the most prevalent health challenge in the study area. 63% of farmers experienced heart-water in their livestock in the study area. Majority of farmers (69%) from the three villages did not vaccinate their livestock while31% use Terramycin, an antibiotic, to prevent diseases. The results further confirmed that internal parasites were not a major issue for farmers, while 69% indicated they did not experience any problem with their goats.

About 29% of farmers indicated they had encountered abortions at least once in their herd during droughts. They associated the abortions with stress caused by winter. Grazing plants during this season are deficient in a number of minerals and other vital elements necessary for the nutritional build-up of animals. About 71% of farmers did not agree to this assertion. About 75% of farmers took measures to control parasites by providing their livestock with gall powder, 75% of farmers dip their goats to prevent ticks which could transmit disease while 72% of farmers did not treat their goats with antibiotics.

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3.5.5 Constraints to goat production

Some of the major constraints faced by farmers in terms of goat production in the study area were as follows: stock theft (45%); malnutrition (33%); and diseases (32%). The results obtained in this study showed a variation in the number of animals owned by farmers and their level of education. Less than 15% of the farmers who had primary level of education had more goats, compared to farmers with tertiary education and farmers with high school education. Farmers with formal education constituted the lowest percentage (10.1%). Goats were ranked as first priority followed by cattle. In addition, it was observed that farmers with primary education had more cattle, representing 11.2% compared to those with formal education with only 4.3%. In terms of chickens, pigs and donkeys, all respondents from the three villages sampled did not consider them as a priority. It is, thus, concluded in this study that many people in the study area are involved in goat farming compared to cattle.

Table 3.8: Major constraints faced by goat farmers around Mafikeng

Major Constraint	Ramatlabama 600 (%)	Tsetse (%)	Lokaleng (%)
Diseases	35.7	15.0	39.0
Stock theft	37.1	55.0	36.0
Malnutrition	7.1	30.0	22.0
Others	20.1	5.0	3.0

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Table 3.9: Variation in the number of animals owned on basis of level of education of respondents

Level of education	Sheep	Goats	Cattle	Chickens	Pigs
Tertiary	4.3±1.8	13.9±2.8	10.1±2.5	3.7±2.4	0.0±0.0
High school	5.5±1.3	12.4±1.1	10.3±1.9	3.4±1.2	0.7±0.4
Primary	4.34±1.0	13.14±0.7	11.2±1.5	5.10±1.4	0.0±0.0
No Formal education	1.1±0.6	10.1±0.8	4.3±1.6	6.6±3.0	0.0±0.0

Data on the effects of gender on goat farming in the study area (presented in Table 3.10) showed that although female respondents had more goats (12.7%) than males (12.5%), (0.2%) this difference was not statistically significant ($p>0.05$).With regard to the correlation between farmers' age and ownership of livestock (Table 3.11), the results showed that older people (between 61 and 70), had more goats compared to the younger generation. Farmers aged between 61 and 70 had 14.7 % of goats while those aged between 31 and 40 had 7.6% of goats.

The results in Table 3.12 show the correlation between the systems of production and the number of goats owned by respondents. 20.0% of farmers involved in semi-intensive farming had more sheep in the study area than other animals. However, with regard to goats, 17.0% were semi-intensive, while 14.0% of farmers practised free range/backyard farming.

Table 3.10: Number of animals owned according to gender of respondents

	Types and numbers of animals owned					
Gender	Sheep	Goats	Cattle	Chickens	Pigs	Donkey
Male	3.9±0.8	12.5±0.7	11.12±1.4	4.3 ±1.0	0.2±0.2	1.12±0.3
Female	4.94 ±1.2	12.7±0.8	8.44±1.5	6.13±1.5	0.19±0.2	1.11±0.3

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Table 3.11: Number of animals owned according to age (years) of respondents

Age	Sheep	Goats	Cattle	Chickens	Pigs	Donkey
31- 40	0.0±0.0	7.60± 2.8	2.50 ±1.5	3.80 ±3.8	0±0.0	0.80± 0.8
41 - 50	4.12 ±1.3	11.53± 1.4	8.50 ±1.7	3.68 ±1.7	0±.0	1.06± 0.6
51 - 60	6.90 ±2.0	6.90± 2.0	14.40 ±1.6	13.30± 2.8	0±0.0	1.20± 0.7
61- 70	5.5 ±1.8	5.5 ±1.8	14.73 ±1.5	13.20± 2.9	1.07±0.6	1.13± 0.7
>70	3.52 ±0.9	3.52± 0.9	12.22 ±0.8	9.07± 1.5	0.97±0.	0.97± 0.3

Table 3.12: Effects of system of production on the number of sheep owned

System of production	Sheep	Goats
Semi-intensive	20.0± 0.0	17.0± 0.0
Free range/backyard	5.5± 1.3	14.0± 0.9

The level of education was independent of gender, age and income as indicated by the statistically insignificant (P>0.05) Cramer's V scores (Table 4.12). In addition, the study also found association between farmers livestock income and supplementation practices, grazing system, access to veterinary services and production systems (Cramer's V=0.048, P>0.05) Concentrates and mineral supplements were independent of livestock income and supplementation practices by statistically insignificant (P>0.05) Cramer's V (Table 3.14). grazing system and access to vet services showed significance.

Table 3.13: Measures of association between level of education and gender, age and income of respondents

	Cramer's V	Significance
Gender	0.017	NS
Age	0.390	NS
Income	0.169	NS

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Table 3.14: Measures of association between livestock income and supplementation practices, grazing system, access to veterinary services and production system

	Cramer’s V	Significance
Concentrates supplements	0.118	NS
Mineral supplements	0.051	NS
Grazing system	0.048	P<0.05
Access to veterinary services	0.037	P<0.05
System of goat production	0.070	NS

Table 3.15 shows measurement of association between concentrates, mineral supplements, access to veterinary services, system of goat production, abortions and Internal parasites according to grazing system, which showed no significant association (p>0.05) according to the strength of association using Cramer’s V score. (Table 3.16). The study showed a significant association (P<0.05) between the level of mineral supplements, the occurrence of abortion and internal parasites on livestock when using Cramer’s V score (Table 3.17).

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Table 3.15: Measures of association between grazing system and provision of concentrates, mineral supplements, access to veterinary services, system of goat production, abortions and internal parasites infestation

	Cramer's V	Significance
Concentrates	0.208	NS
Mineral supplements	0.337	NS
Access to veterinary services	0.201	NS
System of goat production	0.97	NS
Abortions	0.304	NS
Worm Infestation	0.153	NS

Table 3.16: Measures of association between mineral supplements and concentrates according to abortion and Internal parasites

	Cramer's V	Significance
Abortion	0.201	NS
internal parasites infestation	0.63	NS

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Table 3.17: Measures of association between grazing system and goat production according to abortion and Internal parasites

	Cramer's V	Significance
Abortion	0.304	NS
Internal parasites	0.153	NS

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3.6 DISCUSSION

Goats play a very important role in the world, particularly in developing countries, although many countries are meat-oriented (Devendra, 2010). Results obtained in this study on the purpose of keeping animals by farmers correlate with those of Olantunji-Akioke and Adeyemo (2009) who found that in South Western Nigeria, goat is mainly used for meat consumption (highly ranked after cash), especially in the Southern region. Results obtained from the three villages sampled (Ramatlabama 600, Tsetse and Lokaleng) revealed that most respondents kept their goats for personnel reasons and for survival. Most farmers (47%) are more than 70 years making it difficult for them look after their goats (Table 3.2). This a worrying situation because few young people or the youth are involved in farming. This could have an impact in the near future on goat production and on the economy of the country. The future of farming may very well lie in scientific progress, economic interventions, and binding international agreements: however, none of these approaches will succeed without buy- in from those who matter the most (farmers themselves and to be specific, young farmers, who are the future of farming) (Minchew, 2016). A serious investment in youth training on agriculture is important to ensure future agricultural sustainability. This also may explain why stock theft is the major constraint in these areas as mainly unemployed youth are involved in crime. Similar results were reported by Munau *et al*. (2017) in Botswana.

Old people have only basic primary education, thus explaining why they depend on livestock for survival. Low level of education could have an impact on production levels and access to market information. This study is in agreement with the results obtained by Kosgey *et al.* (2006) that low levels of education by farmers have an impact on production and access to market information. Training of farmers will, therefore, empower them and enhance the potential success of breeding programmes, which depend profoundly on record keeping. In this study, most goat owners have primary level of education (Table 3.3). This finding does not agree with the results obtained by Munau *et al*. (2017). In a survey on goat production in Botswana, the authors found that the most common level of education was primary education in almost all the regions, except in the North West region where most respondents had secondary level of education. This is largely because this study focused only on three villages within Ngaka Modiri Molema District. The low proportion of youth who own goats observed in this study was also reported by Munau *et al.* (2017); and Nsoso *et al.* (2004). This is

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unfortunate as they are the future generation of farmers who should ensure the future of the industry.

In this study, 25% of respondents owned land. This could be attributed to the fact that majority of people depend on land to sustain their livelihood (Munau et al., 2017). This has also been reported by several authors (Munau *et al.,* 2017; Kosgey and Okeyo 2017). In this study, 47% of farmers had livestock (cattle, sheep and goats) as their major activity as indicated in Table 3.4. Most owners were not employed and depended on farming for survival. Goats play a direct role as a source of income to other people. This is mainly true for communal goat farmers who sell their goats to speculators who subsequently export them. Speculators gain more profit since the export price is higher (Malher *et al*., 2001). Communal farmers also sell to consumers during Christmas and New Year. There is need to sell more goats in order to generate enough money for school fees the following year. This implies that for communal farmers to have for animals in better condition, and get income, they need to be motivated to invest in improved animal feed and management technologies (Meissner *et al*., 2013). They only sell goats among themselves without weighing them. Goats are usually kept to serve as meat. The findings in this study are similar to those of Mdladla et al. (2017) on the characterisation of village goat production systems in rural communities of the Eastern Cape, Kwazulu Natal, Limpopo and North West Provinces of South Africa. Such findings have also been reported by several authors in Southern African countries (Mahanjana and Cronje 2000; Masika and Mafu 2004; Kunene and Fossey 2006; Beester *et al.* 2009; and Gwaze *et al.,* 2009). However, in Uganda, animal prices depend on the farmer’s need for money and the price the buyer is willing to pay (Ampaire, 2011). About 57% of livestock owners in the study were males while 43% were females. In the three villages sampled, the main reason for keeping goats as advanced by respondents was as a source of income (mainly used for school fees and school uniforms, household commodities and re-stocking of animals). A positive and significant value was observed between grazing system with Cramer’s V=0.0048, $P<0.05$) and access to veterinary services (Cramer’s V=0.037, $P<0.05$). In terms of health issues, diseases are evident, such as brucellosis/abortions and heart water. These are limiting factors to goat production in South Africa. Another issue raised in the study was stock theft in all the three villages. Stock theft is very high in the study area since most of the owners are very old. Livestock is usually stolen at night from the kraal. Some respondents indicated that their livestock were stolen during the day because they did not have money to pay someone to look after their goats. They allowed their goats to browse

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without supervision. Most owners of goats in the study area were pensioners and could not afford to hire someone to look after their goats. The main challenge faced by smallholder farmers was obtaining feed (due to harsh conditions under which goat production systems are carried out). The quality of forage is very poor, thus resulting in poor nutrition. According to Echavarria-Chairez *et al.* (2010), certain policies that tend to ban grazing, makes the pastoralist sector more vulnerable. Goat producers are poor and do not have enough resources to solve their challenges, or to apply impact technologies; they need adequate policies and investment by government and developments agencies. One would expect to find high worm burdens in goats on overgrazed communal pastures, leading to severe diseases and deaths. In terms of access to veterinary services, the results were significant (P=0.037). As well as for grazing system, the results were also significant. However, goat production system was not significant (P>0.05). Therefore, strategies for community based selection and animal health, accompanied by nutrition improvements may have a greater impact on small producers than sophisticated programmes for genetic improvement in rural areas where no production records are kept (Iniguez, 2011). Most households attained relatively low levels of education, which could have an impact on production methods, management ability, record keeping and access to market information (Kosgey et al., 2006). The low level observed in this study is also reported by Munau *et al.* (2017) and Nsoso *et al.* (2004). Most respondents in three villages sampled were not formally employed and depended on a livestock production system for financial income and household food security. This dependency of rural of rural livelihoods on livestock production is a common phenomenon in developing countries and is also seen as an opportunity for efficient use of resources (Kosgey and Okeyo, 2007). The overall flock size was similar to that reported by Dube (2015) in the Eastern Cape of South Africa but consistent with Homann *et al.* (2007) who reported lower flock size of 8 per household in Zimbabwe. Shumbusho *et al.* (2013) found that large flock sizes and record keeping are important for the development of breeding programmes, especially for selection intensity and genetic gain. Therefore, participative research and development in these aspects should be carried out to strengthen subsistence farming where goats are considered as a poor man’s cow.

3.7 CONCLUSION

In conclusion, although Tswana goats of Southern Africa are hardy, their productivity is hindered by several constraints that include high prevalence of diseases and abortions,

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internal parasites factored by limited availability of feed and poor marketing. There is a need for farmers to improve their levels of management, to put their efforts together in order to be able to improve productivity for their benefits. Hence the need to train farmers on record-keeping as all goat farmers interviewed in this study did not keep records which, therefore, will provide farmer's information on feed resources, production and prevalent disease symptoms. There is also need for the government to improve service delivery in terms of veterinary services as farmers had limited access to veterinary extension and as a result, reported disease symptoms and not the diseases diagnosed. Other management aspects, such as record keeping on production and economic records, should be encouraged, so as to develop skills to improve the whole communal production system to benefit the farmer.

It was observed that most farmers have no formal training in herd health management. There is a strong need for training of farmers and education to ensure improvement with regard to production. The development and access to markets will allow farmers to sell and move from subsistence to commercial farming and improve their incomes. This will also ensure incentives for farmers to appreciate the need to improve the levels of management, control of diseases, parasites and improve levels of nutrition. It is, therefore, important to train farmers and develop programmes to address these constraints. There is also need to introduce genetic pool control to improve the Tswana goat breed as inbreeding in communal areas remain a constraint and could reduce the quality of the breed with time.

Farmers need to be empowered with knowledge and skills to improve their farming management practices. The causes of kid mortality need to be clearly defined for farmers to be able to take precautionary measures.

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CHAPTER FOUR: IMPACT OF DIFFERENT DIETARY PROTEIN LEVELS ON MINERALS AND BLOOD PARAMETERS IN TSWANA GOATS

4.1 ABSTRACT

Analysis of haematological parameters allows for the monitoring and evaluation of the health and nutritional status of animals. In this study, an experiment was conducted to determine the impact of different dietary protein levels on goats, blood minerals and other blood parameters of Tswana goats reared in extensive production systems. Twenty-five female Tswana weaner goats with similar body weights and age were used for the experiment. Animals were grouped into three treatment groups of eight goats each in a randomised block design according to live weight. Animals were fed as follows: protein 23.51g and energy 8.55g per kg DM and then given Lucerne *ad libitum*. Blood samples were collected on the first day of the experiment and then weekly until the end of the experiment after 365 days. Samples collected were analysed for blood biochemistry and haematological parameters using the IDEXX Haematology Analyser.

The results obtained revealed that different levels of protein supplementation in Tswana goats significantly affected blood glucose, albumin, albuglobulin and urea ($P<0.05$), respectively. However, no statistically significant differences were observed for levels of serum total protein, globulin, lipase, triglycerides and cholesterol and they were within the reference value for goats. In addition, it was also noted that haematological parameters were influenced significantly ($P<0.05$) by physiological stages of animals.

Keywords: Albumin, energy, growth performance, Haematology, production, protein, Supplementation.

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4.2 INTRODUCTION

Blood is an important medium in assessing the health status of animals (Brown *et al.*, 2016). The physiological and pathological conditions of animals can be assessed by haematological and biochemical analyses of blood (Khan et al., 2011). Concentration of metabolites and enzymes in blood serum are biochemical values with strong relationship to physiological events in goats (Zulkifli et al., 2010). According to Brown *et al*. (2016), Tswana goats are important domestic animals in some regions, especially Limpopo, South Africa. Furthermore, Mutubatse *et al.* (2008) state that goats contribute immensely to the economy and food security of many smallholder farms in the area. However, their productivity is constrained by shortage of good quality feed, especially during the long dry season (Brown *et al.,* 2016).

Brown *et al*., (2016) reported that blood profiles of animals are particularly sensitive to changes in environmental temperature, and is an important indicator of physiological responses to stressing agents in goats. According to Gupta *et al*. (2007), examining blood for their constituents is used to monitor and evaluate health and nutrition status of animals. According to Madan *et al.* (2016) haematological, biochemical, and mineral profiles are important to be determined because they provide valuable information about the breed, sex and health status of animals. There is considerable information about the normal parameters of blood of domestic animal species, however, the values are expected to vary according to breed, different environmental factors and different methods of management (Sharma *et al*., 2012). Shah *et al.* (2007) reported that physiological adaptation and systemic relationship are widely determined using haematological values. Biochemical profile shows some changes and blood plasma components vary according to growth requirements, breed, ages (Piccione *et al.*, 2007), environmental factors, management conditions, sexual maturity (Piccione *et al*., 2012) and the productivity of animals (Madan *et al*., 2016). The experiment was conducted to assess the impact of different dietary protein levels on Tswana goat minerals and blood parameters.

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4.3 MATERIAL AND METHODS

4.3.1 Animals in the study area

Figure 4.1: Tswana goats used in this study

The study, which was approved by the Ethics Committee of the North-West University, Mafikeng Campus, South Africa, was performed in accordance with Animal Health guidelines in terms of care and use of experimental animals. The study was conducted at the Molelwane Farm of the North- West University, Mafikeng Campus, North West Province, South Africa from March 2014 to February 2015. Mafikeng is located at 25°52'S and 25°38'E (Figure 4.2) below. It is a semi- arid environment with a savannah type vegetation and summer rainfall averaging 540 mm per year. It has one long dry season (winter), from May to October and a relatively short wet season (summer), from November to February.

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Figure 4.2: Map of Mafikeng, North-West Province, South Africa

4.3.2 Experimental design

Twenty-five female Tswana weaner goats, with similar body weight and age (3 months old and 10.56±1.28 kg BW), were bought from local farmers around Mafikeng (Figure 4.3). The goats were ear-tagged and allowed to adapt for two weeks to the experimental conditions prior to the commencement of the study. All animals were dewormed with an anthelmintic drug (Prodose from Virbac) two weeks before the start of the trial. They were also vaccinated against pulpy kidney, anthrax and heart water diseases.

Based on body weight, the animals were randomly allocated into three treatment groups (8 goats per treatment) in a completely randomised design (CRD). The does were penned individually in a well-ventilated pen, supplemented with the level of crude protein 23.51g and energy 8.55g per kg. Goats were also fed basal diet of hay *ad libitum* and had free access to fresh water.

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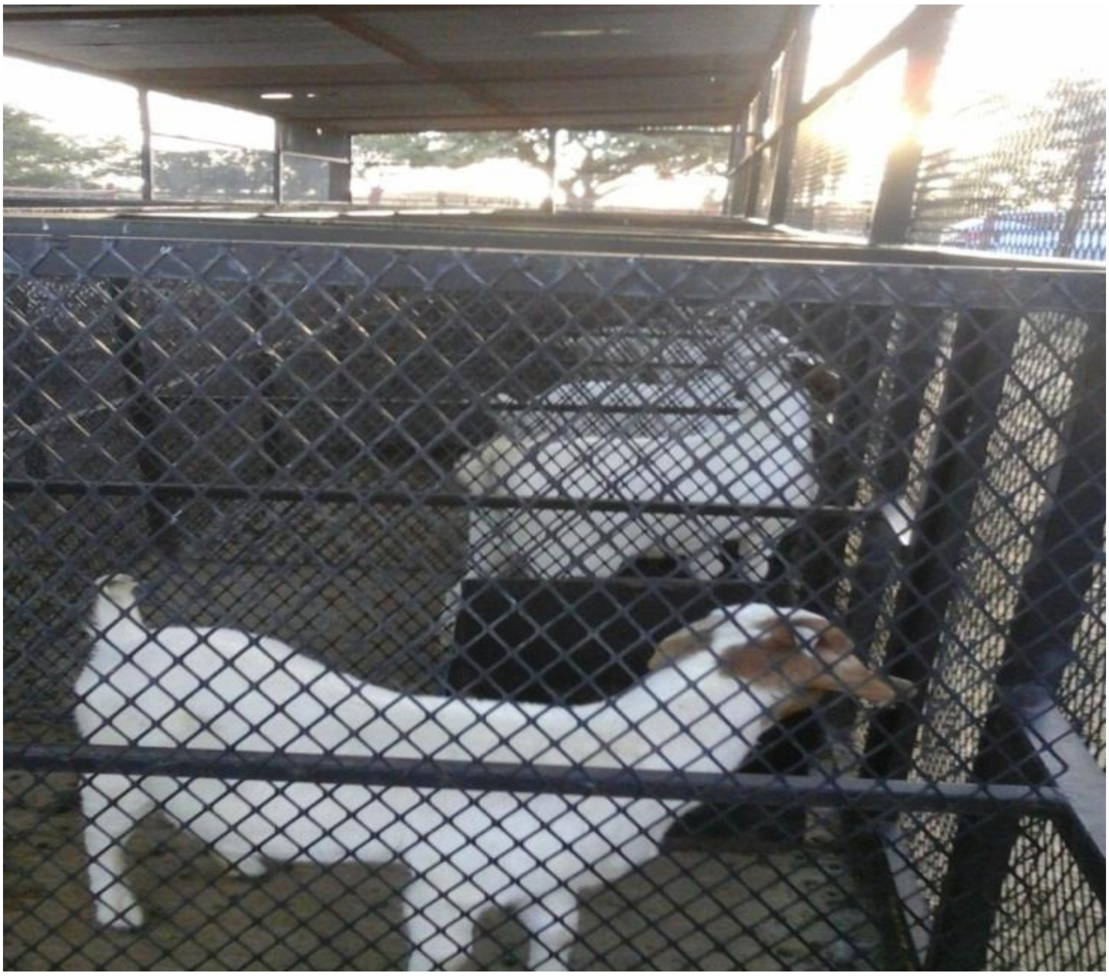

Figure 4.3: Picture of does used during the experiment, penned individually in a well-ventilated pen and fed individually

4.3.3 Feeding and management

Goats were fed with concentrate-based diets once daily (at 09:00 hours) and later given grass *ad libitum* and had access to water. Feeding allocations and refusal to eat were recorded daily for each goat. Animals were weighed monthly prior to the morning feeding. The goats were bred when they reached sexual maturity and monitored throughout the day. Blood was collected from the goats at 08:00 and further measurement of minerals (phosphorus, calcium and magnesium), nutritional metabolites and reproductive hormones. All animals were kept in pens throughout the study(365 days).

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4.3.4 Diets and feed supplementation

Animals were supplemented with concentrate mixtures consisting of maize, grass and soybean meal, based on their weight and nutritional requirements as follows: Treatment 1: maintenance X 1; Treatment 2: maintenance X 2; and Treatment 3: maintenance X 3 (Webb, 2010). The increment of supplemental diets was based on live weight gain and daily feed consumption. In addition, all animals had free access to drinking water.

4.3.5 Blood collection and analysis

Blood collection was done by a qualified animal health technician through the jugular vein. 10 ml of blood was collected immediately after restraint to minimise the effect of excitement on the mineral levels of blood, especially phosphorus (McDowell *et al*., 1982). Blood was collected on the first day of the experiment and every second week post-feeding into one set of sterilised bottles, containing ethylene-diamine tetra acetic acid (EDTA) as the anti-coagulant.

Blood samples were then stored for 24 hours at 4°C to allow adequate separation of the serum from the clot. Clotted blood (collected in red stoppered tubes) was centrifuged in a macro centrifuge at 10,000 rpm (revolution per minute) for ten minutes to extract the serum for biochemical analysis and the serum separated from the clot. Care was taken to avoid haemolysis of the samples and to minimise inconsistent mineral levels, especially phosphorus (McDowell *et al*., 1982).

4.3.6 Biochemistry

Total protein (TP), Urea (BUN), Glucose (GLUC), Globulin (GLOB), Triglycerides (TRIG), Cholesterol (CHOL), Lipase (LIPA) and Albumin (ALB) were analysed using Idexx catalyst Dx^{tm} according to the manufacturer' s instructions (IDEXX Laboratories, Inc., 2016).

4.3.7 Hormonal analysis

Progesterone was analysed using high performance liquid chromatography (HPLC) (model Shimadzu SPD-M20A) and the Ultra Violet Detection method according to Augustine *et al.* (2014), with minor modifications. Blood samples were drawn from goats into serum tubes containing no anti-coagulant and allowed to clot at room temperature for 30 minutes. Serum

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was separated by centrifugation and 0.5 mL of serum samples stored at -20°C until analysis. Samples were thawed on ice and 0.5 mL of serum transferred into a 10 ml centrifuge tube. Samples were run in duplicates. 1 ml of potassium phosphate and 4 ml pentane were added to the samples. The mixtures were vortexed thoroughly to mix, shaken for 15 minutes at room temperature and centrifuged at 1250 rpm for 10 minutes. Occasionally, a gel interface formed between the aqueous and organic layers. This was observed more often if the samples were placed on ice or refrigerated for an extended period of time. When this occurred, the samples were vortexed thoroughly and centrifuged at a higher speed to obtain a clean solvent phase separation (approximately 1800-3000rpm).

After centrifugation, the organic phase was collected into a separate clean 10 ml centrifuge tube and the extraction repeated as above with 2 ml pentane. The organic phases (from the first and second extraction) were combined and subsequently dried under a stream of nitrogen gas. The dried samples were reconstituted in 100ml HPLC sterile water/methanol (50/50), while being cautious to wash down the sides of the tube and mix thoroughly. A brief centrifugation at 1250 rpm for 5 minutes was performed to concentrate the sample in the base of centrifuge tube. The samples were then transferred into injection vials for analysis by HPLC. The HPLC analytical column stood at C18 (300X4.0 mm id). Progesterone standard and samples were analysed using a UV detector (minimum wavelength 495 nm to maximum of 516 nm) in a condition and temperature of between 36^0C and 40^0C, HPLC pump flow rate of 1ml per minute and injection volume of 100µl (Figure 4.4). The retention time of the standard was 5 minutes while for the samples, it was 8 minutes. The concentration of the standard ranged from 200ng/ml to 1000ng/ml.

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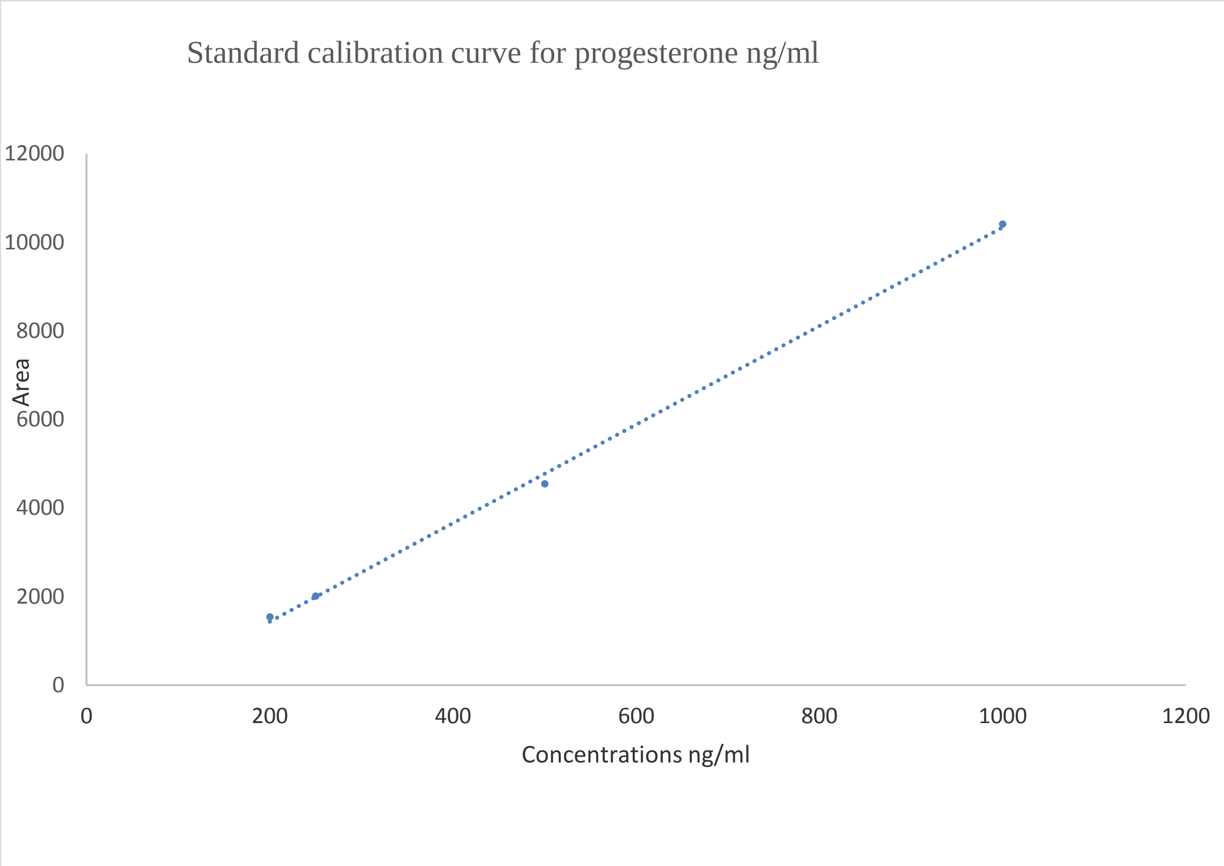

Figure 4.4: Standard calibration curve for progesterone analysed on HPLC using a UV detector Concentrations ng/ml.

4.3.8 Minerals

Minerals (phosphorus, calcium and magnesium) were analysed using ICP Mass Spectrometer (Nexion 300Q Model, 2010, Perkin Elmer SA (Pty) Ltd) according to Tsheole *et al.* (2016). The concentration levels of protein and energy from the results were expected to reveal whether supplementation of protein, energy and minerals had an effect on performance and reproductive health of goats reared in extensive production in the study area. The following methodology was used: two ml of digested samples were mixed with 8 ml of 8 Lanthanum Chloride in 10 ml test tubes and read through an atomic absorption spectrophotometer (The Analyst 700 Model.

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4.4 STATISTICAL ANALYSES

Minerals and blood nutritional metabolite data were analysed using repeated measures on the procedures of SAS (SAS, 2015) on the General Linear Model (GLM) according to the following linear model:

$$Y_{ij} = \mu + D_i + E_{ij} \text{ ,}$$

Where: *Yij*=observation of the dependent variable *ij;*

μ = fixed effect of population mean for the variable;

D_i = effect of dietary treatment (i = 4); and

E_{ij} = random error associated with observation *ij*, assumed to be normally and independently distributed.

Statistical significance was declared at p<0.05.When the analysis of variance revealed the existence of significant difference among treatment means, the probability of difference (PDIFF) option in the LSMEANs statement of the GLM procedure of SAS (2015) was used to separate the means. The level of significance was set at p<0.05.

4.5 RESULTS

4.5.1 Effect of supplementation of the level of blood glucose

The effect of dietary protein on blood glucose in Tswana goats is shown in Table 4.1 and Figure 4.5. Protein supplementation had a significant (p<0.05) effect on glucose concentration over time and between treatments. Glucose concentrations varied between 3.31 Mmol/L at the beginning of the experiment and 1.28 Mmol/L at the end of the experiment after parturition. There was a significant difference (p<0.05) between treatment with high concentrations (3.31 in week 1 -1.29 Mmol/L in week 39) for treatment 3 and 3.31 in week 1 -1.40 in week 39 and 3.31 in week 1 -1.28 in week 39 Mmol/L, respectively, for treatments 2 and 1. There was a decrease in glucose concentration proportionally in the 3 treatments from week 16 (early puberty and pregnancy to week 24). A recovery was observed until parturitions around week 36.

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Table 4.1: Serum glucose levels in Tswana goats fed dietary protein at three levels (Mmol/L)

	Weeks										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	3.31±0.5	2.04±0.1	1.74±0.0	1.94±0.1	2.23±0.2	0.86±0.1[a]	1.84±0.1	1.42±0.1	1.74±0.1	1.17±0.0	1.28±1.3
Treatment 2	3.31±0.4	1.98±0.1	1.64±0.0	1.97±0.1	1.81±0.2	0.94±0.1[a]	1.84±0.1	1.42±0.1	1.79±0.1	1.09±0.0	1.40±1.5
Treatment 3	3.31±0.6	2.09±0.2	1.62±0.1	1.92±0.1	1.88±0.2	1.35±0.1[b]	1.88±0.1	1.36±0.1	1.69±0.1	0.98±0.0	1.29±1.9

a,b Means with different superscript on the same column are significantly different (P<0.05).

Treatment 1= maintenance X 1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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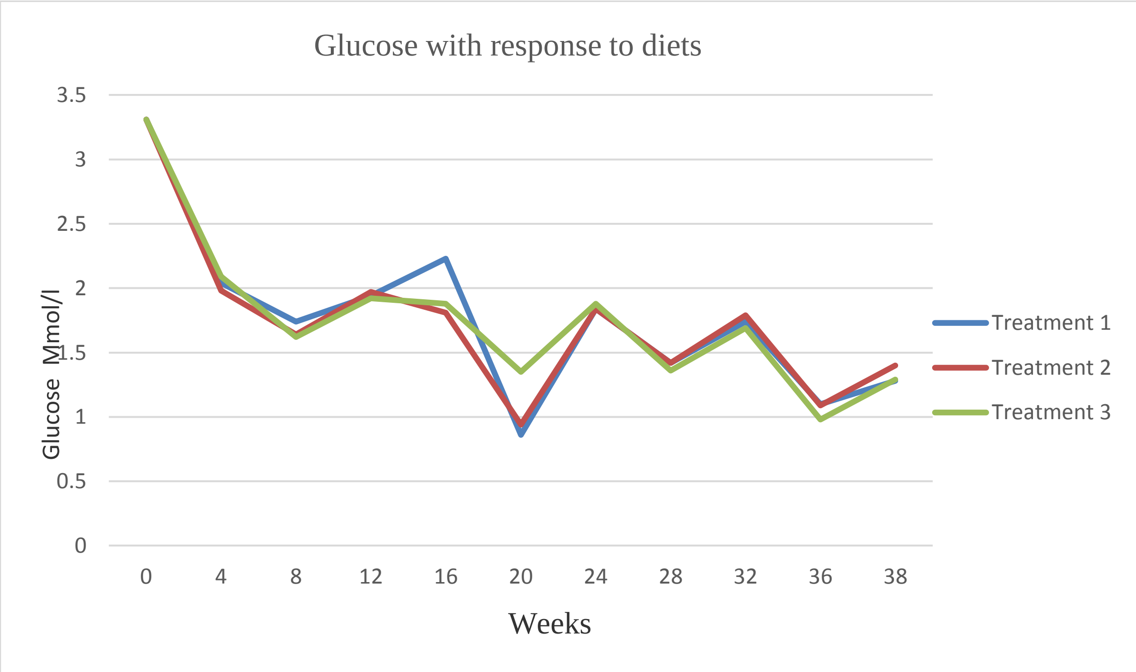

Figure 4.5: Levels of blood glucose variation over time in Tswana goats supplemented with protein in three treatments

Effect of protein supplementation on serum Albumin

Data obtained in this study and presented in Table 4.6 and Figure 4.6 revealed that protein supplementation administered to Tswana goats had an impact on serum globulin concentrations. Significant difference ($p<0.05$) in serum concentrations were observed between the three treatments (through the period of experiment). In addition, significant increases were observed from week 20 with concentrations reaching peaks of 35.4, 38.1 and 39.2, respectively, in treatments 1, 2 and 3 around week 28 and then a drop around week 32 before an increase again after parturition (week 36). Overall, it was observed that Albumin concentrations were proportional to protein supplementation with higher concentrations observed in treatment 3 followed by treatments 2 and 1.

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Table 4.2: Mean values of serum Albumin concentrations in Tswana goats supplemented with protein at different concentrations (Mmol/L)

	Weeks										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	27.3±1.3	24.60±1.4[ab]	26.1±2.5	25.6±2.3	26.9±0.7	28.9±3.0	28.4±0.8	35.4±2.0	28.1±0.4[a]	26.7±0.7	26.0±0.0
Treatment 2	27.3±1.2	26.75±1.3[b]	27.1±2.4	28.0±2.2	27.1±0.7	29.3±2.8	29.3±0.7	38.1±1.8	28.7±0.4[a]	27.4±0.7	28.2±3.0
Treatment 3	27.3±1.4	28.16±1.5[a]	28.7±2.7	29.3±2.5	28.3±0.8	30.3±3.3	29.5±0.9	39.2±2.1	30.4±0.5[b]	28.2±0.8	30.7±4.0

a,b Means with different superscripts on the same column are significantly different ($P<0.05$).

Treatment 1= maintenance X 1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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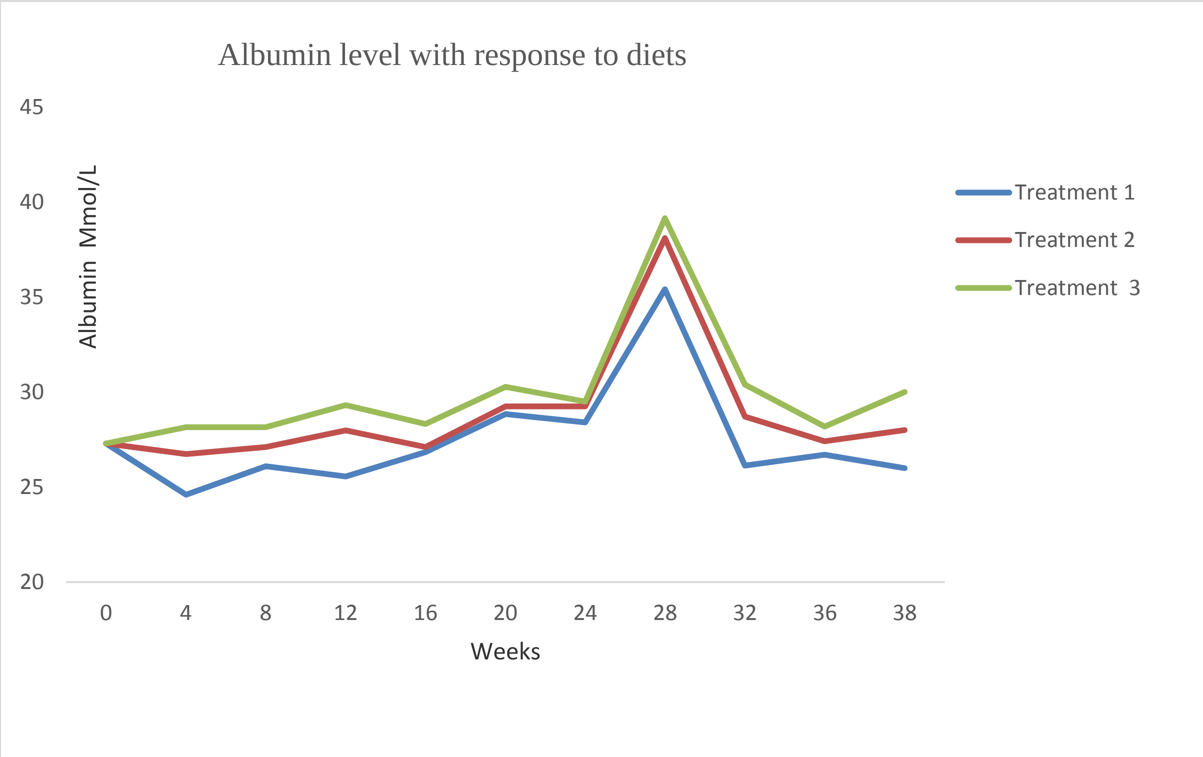

Figure 4.6 Albumin variations in Tswana goats supplemented with different concentrations of protein in feed

There was significant difference (p<0.05) in serum albuglobulin concentrations between the three treatments of Tswana goats fed with protein at different ratios.

Significant differences (p<0.05) were observed in the increase of serum albuglobulin over time in all three treatment groups (0.70 -0.78 for treatment 1; 0.75 -0.78 for treatment 2 and 0.61 to 0.80 Mmol/L for treatments 3 from week 0 to week 38) (Table 4.3, Figure 4.7).

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Table 4.3: Mean values of serum Albuglobulin variations in Tswana goats supplemented with protein at different concentrations. (Mmol/L)

	Week										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	0.70±.03[ab]	0.61±.03	0.72±.02	0.72±.04	0.70±.01	0.68±.03	0.65±.02	0.68±.02	0.65±.03[a]	0.72±.03	0.78±.02
Treatment 2	0.70±.02[b]	0.62±.03	0.73±.02	0.75±.04	0.71±.01	0.67±.03	0.72±.02	0.71±.01	0.72±.03[a]	0.71±.03	0.78±.02
Treatment 3	0.70±.03[a]	0.63±.03	0.76±.03	0.77±.04	0.71±.01	0.68±.03	0.66±.03	0.73±.02	0.76±.76[ab]	0.72±.03	0.80±.03

a,b Means with different superscripts on the same column are significantly different ($p<0.05$).

Treatment 1= maintenance X 1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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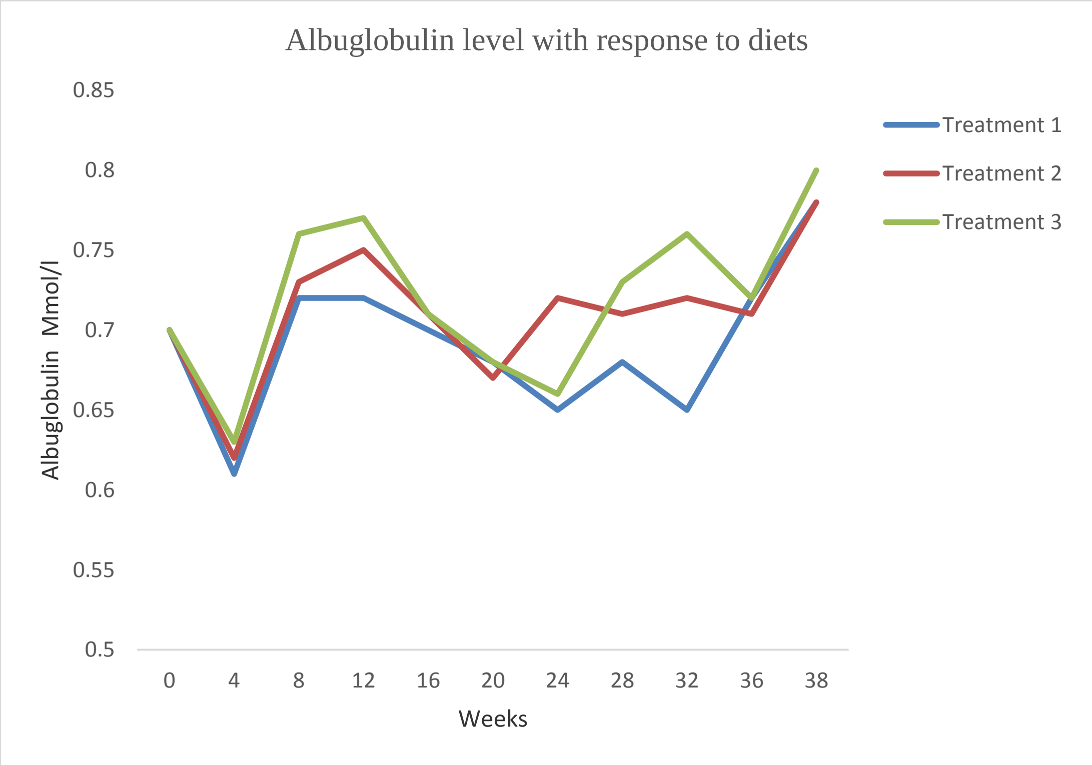

Figure 4.7: Graph of dietary protein on Albuglobulin protein in Tswana goats

Data obtained in this study showed significant differences ($p<0.05$) between the three treatments Alglobulins during the period of experimentation. In addition, it was observed that Urea concentrations varied significantly ($p<0.05$) in all three treatment groups between the beginning and end of the experiment (Table 4.3). Increases in concentrations were observed from week 16 reaching a peak at week 24, then a decrease around week 28 and then a progressive increase from week 32 (Figure 4.8).

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Table 4.4: Serum urea variations in Tswana goats supplemented with protein at 3 different concentrations (Mmol/L)

	Weeks										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	9.02±0.6	6.04±0.7	8.24±0.2	5.81±0.7	4.11±0.6	7.12±0.4	9.51±8.0	6.02±0.5	7.15±0.4	9.14±1.0	11.18±0.6
Treatment 2	9.02±0.6	7.02±0.6	9.57±0.2	7.88±0.6	5.07±0.6	8.90±0.4	10.92±7.5	7.06±0.4	8.15±0.4	10.92±1.0	12.32±0.7
Treatment 3	9.02±0.6	8.53±0.7	10.16±0.3	9.46±0.7	6.28±0.7	9.48±0.4	11.53±8.6	8.18±0.5	9.67±0.4	11.34±1.2	13.33±0.9

Treatment 1= maintenance X 1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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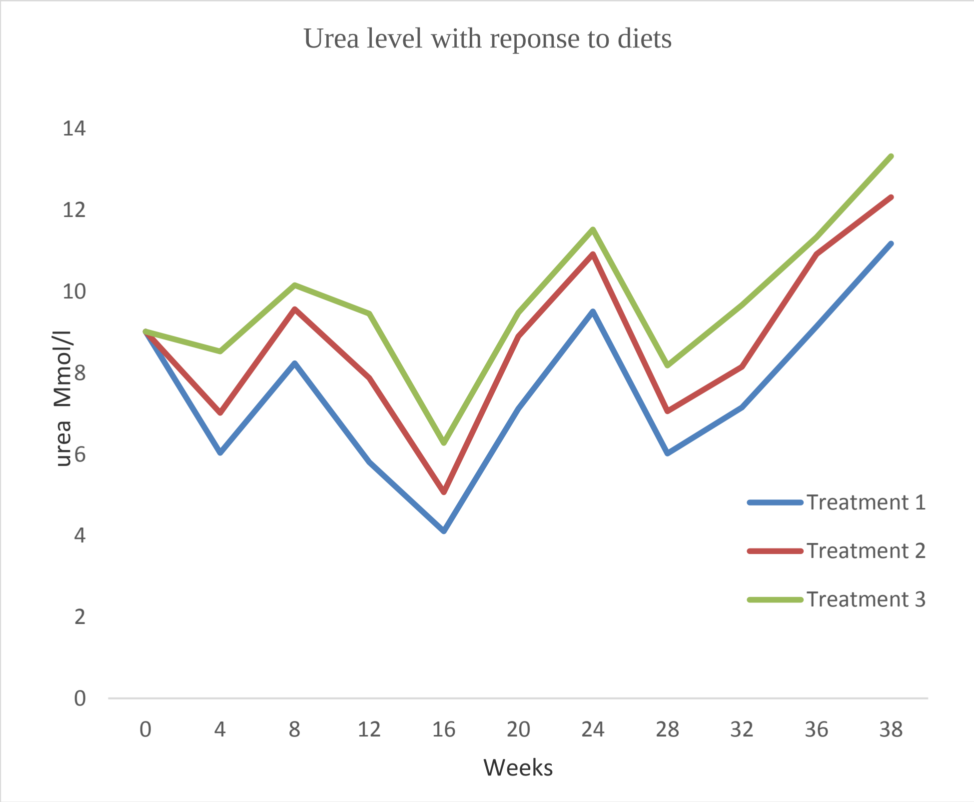

Figure 4.8: Graph of serum urea in Tswana goats supplemented with different concentrations of protein in feed

Total serum protein concentration was significantly ($p<0.05$) affected by protein supplementation over time of experiment, with concentrations varying between 66.3 and 73. Mmol/L 5; for treatment 1, 66.3 to 73.0 Mmol/L for treatment 2 and 66.3 to 71.7 Mmol/L for treatment 3 from week 0 to week 38 of the experiment (Table 4.4). An increase in concentration was observed between weeks 16 and 28 with highest concentrations of 72.9 for treatment 1, 70.8 for treatment 3, and 76.0 Mmol/L for treatment 3, recorded around week 20.

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Table 4.5: Serum total protein on Tswana goats in three dietary treatments (Mmol/L).

	Weeks										
	0	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	66.3±2.3	61.1±2.4	66.4±2.0	63.7±3.9	65.6±1.7	72.9±2.2	70.3±1.8	69.0±1.1	70.9±1.3	67.4±1.6	73.5±1.7
Treatment 2	66.3±2.1	62.1±2.2	64.6±1.8	65.5±3.7	65.3±1.6	70.8±2.1	69.6±1.7	67.3±1.0	69.0±1.3	65.6±1.5	73.0±1.9
Treatment 3	66.3±2.5	63.3±2.5	69.5±2.1	72.0±4.2	69.0±1.8	76.0±2.4	73.3±2.0	68.8±1.2	72.7±1.4	68.2±1.9	71.7±2.5

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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Figure 4.9: serum total protein in Tswana goats

In this study, it was found that protein supplementation administered to Tswana goats affected the levels of serum globulin over time. Data obtained also revealed an increase in serum globulin, starting at week 4 and reaching a peak at 42.3, 41.5 and 45.2 Mmol/L respectively for treatment groups 1, 2 and 3 at week 20 before declining to reach the lowest value around week 28.

`

Table 4.6: Serum globulin levels in Tswana goats fed 3 different levels of protein (Mmol/L).

Treatment	Weeks										
	0	4	8	12	16	20	24	28	32	36	38
Treatment 1	31.3±1.4	37.1±1.3	38.3±1.1	39.9±2.1	38.7±1.1	42.3±1.5	41.9±1.3	40.4±0.6	42.7±0.9	36.9±1.3	38.8±1.2
Treatment 2	31.3±1.3	37.5±1.3	37.5±1.0	39.1±2.0	38.0±1.0	41.5±1.4	40.5±1.2	39.3±0.6	40.3±0.9	39.4±1.3	40.4±1.3
Treatment 3	31.3±1.5	35.5±1.5	40.8±1.2	40.3±2.3	40.7±1.1	45.2±1.7	43.8±1.4	40.3±0.7	43.3±1.1	39.4±1.5	41.7±1.7

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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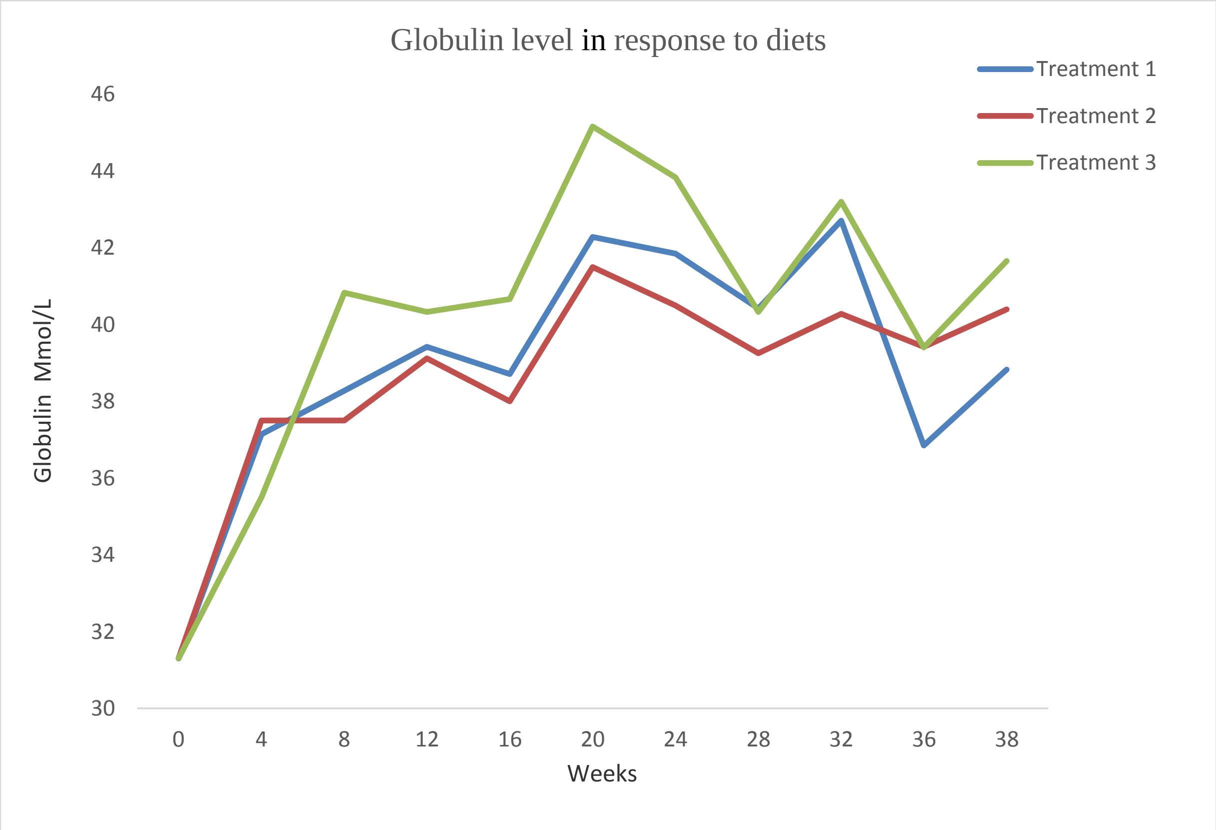

Figure 4.10: Globulin levels in response to 3 diets

Lipase concentrations were affected by supplementation of protein in Tswana goats. There was no pattern regarding the concentrations of Serum Lipase over the experimental period. Concentrations increased and decreased between weeks 8 and 36. No significant differences were observed between the three treatment groups.

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Table 4.7: Serum lipase levels in Tswana goats fed 3 different levels of protein (Mmol/L).

	Weeks										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	218±26.5	209±57.7	209±17.6	278±48.3	230±29.4	203±20.2	183±16.1	264±18.1	237±17.8	203±25.1	246±21.9
Treatment 2	218±24.8	211±54.0	204±16.5	279±45.2	264±27.5	229±18.9	199±15.0	241±16.9	287±17.8	201±25.1	235±23.9
Treatment 3	218.±28.7	213±62.3	230±19.1	289±52.2	230±31.7	227±21.8	199±17.4	257±19.6	243±21.0	202±29.7	258±30.8

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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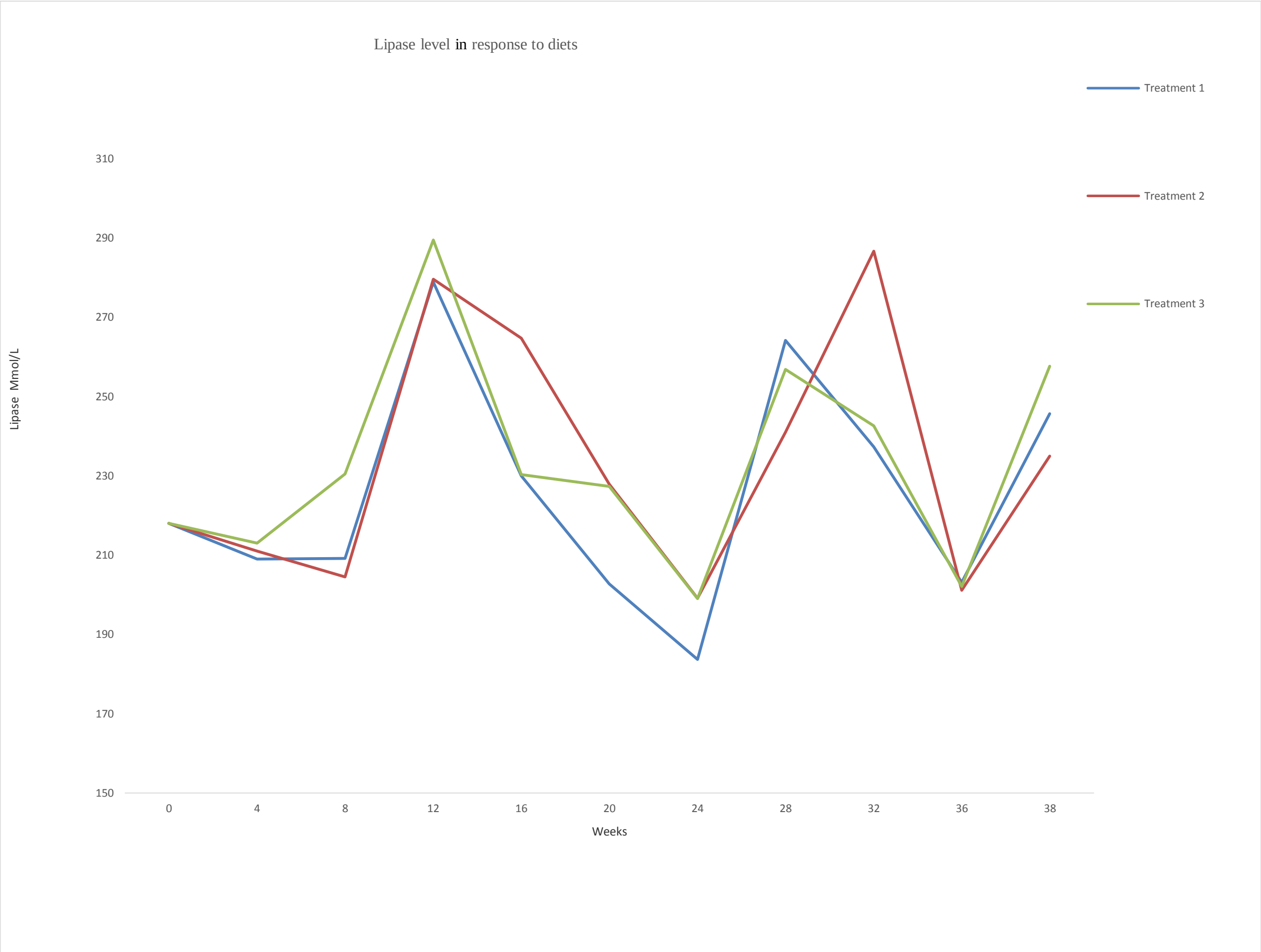

Figure 4.11: Lipase levels in response to 3 diets fed to Tswana goats

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a goats supplemented with feed with different concentrations of protein, showed significant variations of Serum triglyceride over the experimental period. Increases from week 4 with highest peak concentrations of 0.26, 0.30 and 0.18, were observed in treatment groups 1, 2 and 3 respectively in week 16, followed by a decrease around 20 before increasing to stabilise at week 28 and decrease until the end of the experiment (Table 4.8). Significant differences ($P<0.05$) were observed between the three treatment groups with the control group (Treatment1?) recording higher levels of serum triglyceride, followed by treatment groups 2 and 3 respectively (Figure 4.12).

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Table 4.8 Serum Triglycerides levels in Tswana goats fed 3 different diets (Mmol/L).

	Week										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment 1	0.12±0.06	0.13±0.05	0.11±0.00	0.11±0.02	0.26±0.07	0.15±0.01	0.22±0.07	0.24±0.20	0.21±0.02	0.18±0.04	0.11±0.00
Treatment 2	0.12±0.06	0.16±0.05	0.11±0.00	0.14±0.01	0.30±0.06	0.13±0.01	0.22±0.06	0.64±0.18	0.16±0.02	0.13±0.04	0.11±0.00
Treatment 3	0.12±0.07	0.26±0.06	0.11±0.00	0.12±0.02	0.18±0.07	0.13±0.02	0.12±0.07	0.23±0.21	0.21±0.03	0.13±0.04	0.11±0.00

Treatment 1= maintenance X 1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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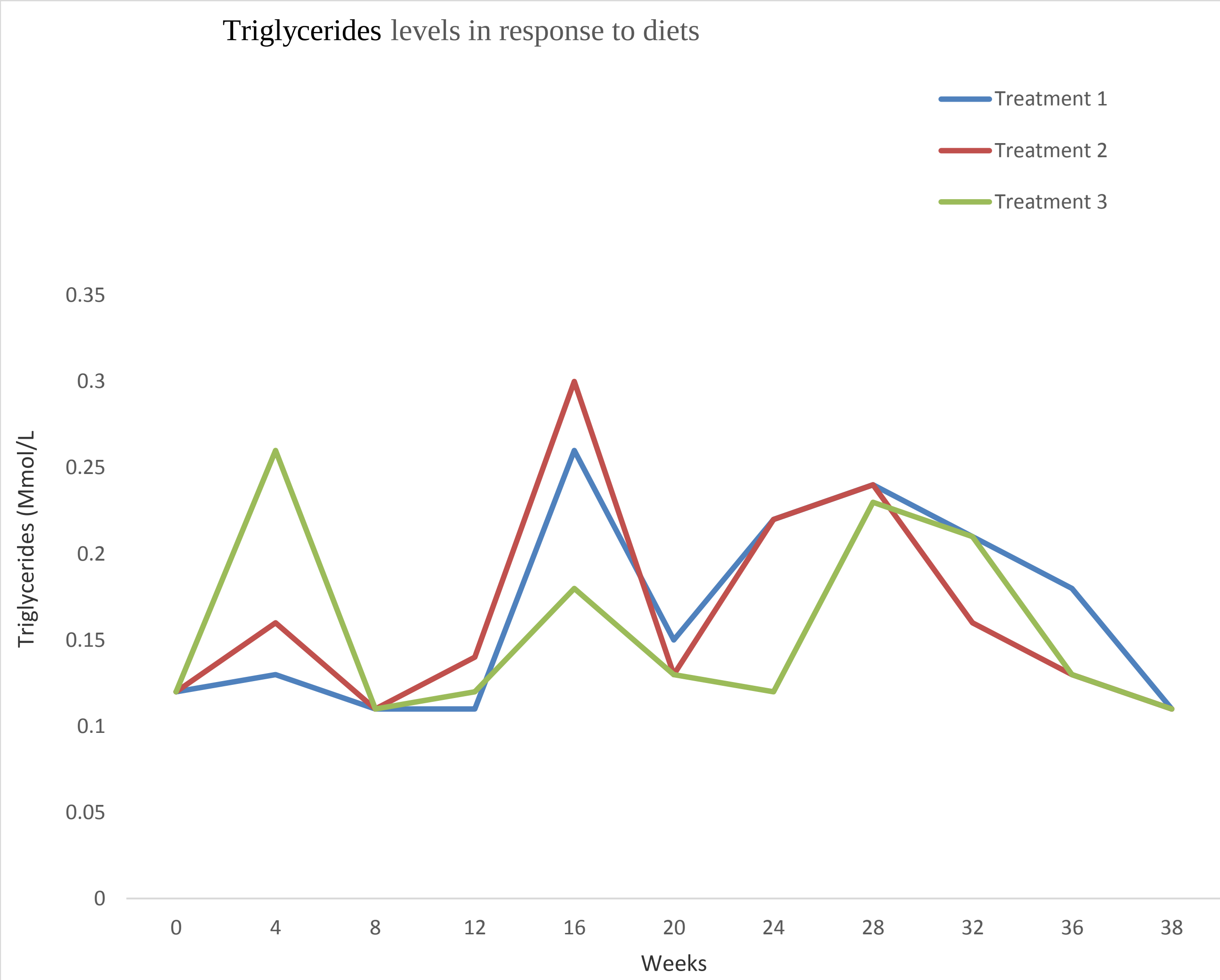

Figure 4.12: Triglycerides levels in response to 3 diets fed to Tswana goats

Results obtained from the experiment supplementing Tswana goats with protein at different concentrations (Table 4.8, Figure 4.13) showed no significant differences between the three treatment groups over the experimental period. However, it was observed that protein supplementation had a significant effect over time on the serum concentration of goats. Concentrations of cholesterol increased progressively around week 12 and reached the peak at week 24, before decreasing to stabilise at week 28 and then slightly increased afterwards (Figure4.8).

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Table 4.9: Serum cholesterol levels in Tswana goats fed 3 different diets (Mmol/L)

	Weeks										
Treatment	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**38**
Treatment1	1.91±0.22	1.65±0.19	1.71±0.15	1.35±0.17	1.61±0.19	1.89±0.15	0.16±0.15	1.79±0.16	1.81±1.81	2.29±0.24	2.38±14.6
Treatment2	1.99±0.20	1.46±0.18	1.95±0.14	1.53±0.16	1.68±0.18	1.93±0.14	2.35±0.14	1.87±0.15	2.05±0.13	2.10±0.24	2.11±17.30
Treatment3	1.71±0.24	1.50±0.21	1.82±0.16	1.72±0.19	1.59±0.21	1.81±0.16	2.28±0.16	1.63±0.17	2.00±0.15	1.90±0.28	5.04±22.44

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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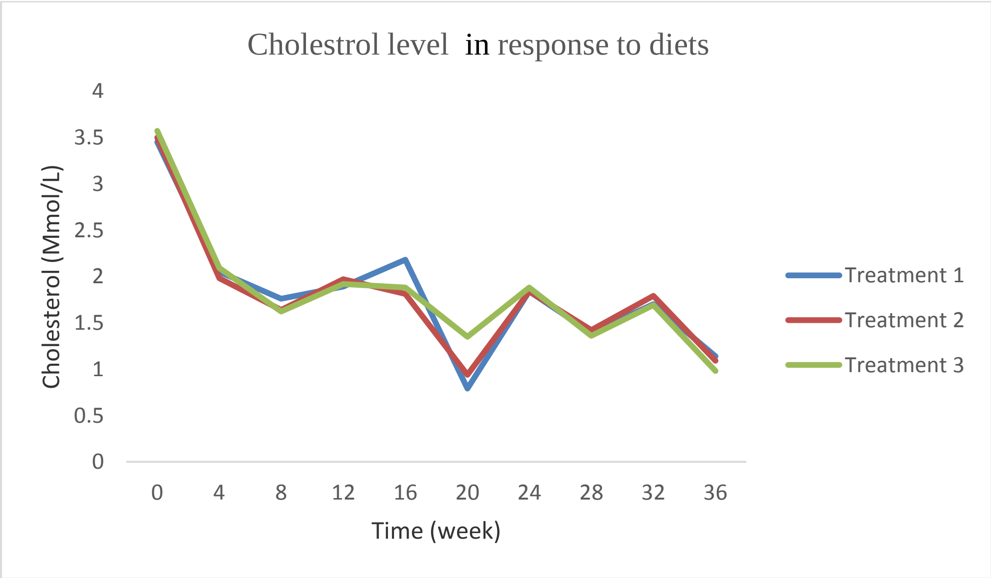

Figure 4.13: Cholesterol levels in blood of Tswana goats in response to 3 diets.

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4.6 DISCUSSION

Serum biochemistry parameters indicate pathophysiological states that help in identifying pathogenesis and cause of diseases (Solaiman *et al.*, 2010). The aim of this chapter was to study the effects of supplementation of feed with different concentrations on the serum biochemistry of Tswana goats. Total protein, serum albumin, serum globulin and urea, are among the important serum biochemical parameters in assessing the health status of a herd (Magnus and Lali, 2009). The results obtained showed that the serum glucose in this study ranged between 0.86 and 1.95 Mmol/L during the experiment, which were within the normal ranges in goats. This is an indication that protein supplementation in Tswana goats may not have an appreciable effect on their blood glucose.

The data was lower than those of Solaiman *et al*. (2010), who recorded serum glucose ranging between 2.78 and 4 Mmol/L. The results obtained in this study are in agreement with those reported by Coles (1986) Benjamin (1989) and Smith (2002), ranging between 2.78 and 3.89 Mmol/L in goats. Serum glucose is indicative of energy levels of the animal (BulentElitok, 2012). In this study, it was observed that the levels of Total Protein were significantly influenced by physiological of the animal than the variability of protein supplementation in goats. The hormonal changes observed during puberty and early pregnancy, characterised by the release of the pituitary gland of hormones such as Luteinising Hormone and Follicular Stimulating Hormone, induced stress and energy consumption in the animal. In addition, blood glucose levels could be affected by the adaptation mechanism, which is influenced by high ambient temperatures (El-Tarabang *et al*., 2016).

Results obtained in this study are in line with those of Solaiman *et al*. (2010) who found that blood glucose was not affected with the increase of tannin-rich *Sericea lespedeza* in the diet of Kiko cross, Serum albumin is indicative of the liver function in the animal (Brown *et al*., 2016), and was also found not to be affected by protein concentration in the feed of the three treatment groups in this study. Significant differences ($p<0.05$) were observed between the three groups. However, serum albumin was influenced by metabolic and physiological changes in animals. The increase of concentrations observed between weeks 24 and 32 of the experiment were because all animals were pregnant. These results are in agreement with those of Diogenes *et al.* (2010); Piccione *et al*. (2011); Brown *et al.* (2016) who did not observe significant influences of supplementation on serum albumin of goats.

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Albumin is a water-soluble protein found in blood, accounting for about 60% of plasma proteins found in blood. The main function of Albumin in blood is to carry fatty acids, thyroid hormones and steroids (Merck, 2016). It can also be used as a binding point for some medications and drugs. Brown *et al*. (2016) reported that serum albumin variations could be affected by many factors such as heat haemo-concentration that could increase its value. This also explains the seasonal variations observed in serum albumin concentrations in goats during the experimental study.

The progressive increase of albumin from weeks 20 to 36 of the experiment, corresponds to the physiological stages of puberty and pregnancy in goats. This increase cannot be explained but could be due to the levels of protein in the feed. Several studies (Brown *et al*., 2016; Palacios *et al.,* 2017; have revealed similar decreases in serum albumin concentration. The main function is to regulate the osmotic pressure of blood as higher albumin levels could be caused by acute infections, burns and stress from surgery or a heart attack (Merck, 2016). Hence, their increase in this study could have been due to some kind of stress related to physiological changes or environmental effects such as heat that animals may have encountered during the experiment.

The results also showed significant statistical differences ($p<0.05$) in albuglobulin concentrations between the three treatment groups, with high concentrations noted in treatment group 3, followed by groups 2 and 1. It is, therefore, concluded that protein supplementation had an impact on albuglobulin levels in treated goats. No significant differences were observed over time. It is important to mention that there was correlation between serum proteins, albumin, creatinine and urea (Nozad *et al*., 2012).

No significant differences ($p>0.05$) were found between the three treatment groups with regard to urea concentrations over the experimental period (Figure 4.8). However, significant differences were observed between the three ($p<0.05$) with diet three showing higher concentrations, followed by diets 2 and 1 respectively. The difference showed that protein supplementation administered to Tswana goats had an effect on urea concentrations. This differentiation could be explained by the fact that urea is a protein degradation by-product, which accumulates in blood if the kidney is affected or if the threshold has been reached. Urea is also known to be a nitrogen source used for the synthesis of proteins in the digestive

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system. In addition, the concentration of Urea in blood is always indicative of more efficient utilisation of amino acid (Cronje, 1992).

However, it was observed that the physiological stages of goats did not significantly influence urea concentrations in the treated groups. In addition, it was noted that there was no increase in concentration in treated groups over time, which could be explained by the fact that urea is used as a source of energy in ruminants since the nitrogen portion of urea is used as a building block for the production of protein by rumen microbes (Merck, 2016).

Data obtained in this study also showed a significant correlation between protein supplementation in Tswana goats and total protein concentration in blood. Significant differences ($p<0.05$) were observed between the three treatments groups. Higher concentrations of serum total protein were observed in treatment groups 3, 2 and 1 during the experimental period. There was a slight increase in total protein concentration from weeks 16 to 36 of the experiment, which corresponded with puberty and pregnancy, while after parturition, significant increases in of concentrations were observed in all three treatment groups. These results are in line with those of Chen et al. (1999); Diogenes *et al.* (2010); Manat *et al*. (2015) who observed an increase in total protein after parturition in goats and bovine. The increase during post-partum could be explained by the increase of globulin and production of immunoglobulin necessary for neonate immunity and growth (Mellado *et al*., 2008). This is an indication that there was correlation between the physiological stage and total protein concentrations over the time of experiment. The results correlate with those of Brown *et al*. (2016) who observed a decrease in serum total protein after supplementing Karroo leaves to goats.

The study revealed that protein supplementation had an effect on serum lipase and globulin concentration in blood (same as for serum total protein, between the three treatment groups). High concentrations were respectively observed in treatment groups 3, 2 and 1. This difference in concentration could be explained by the supplementation of protein in feed since it is known that globulins are large proteins that play an important role in the immunity of the animal. The slight increase observed during pregnancy (as observed in this study) is in line with the findings of Zvorc *et al*. (2000); and Piccione *et al.* (2011) that total proteins, and albumin/globulin could be explained by stress incurred during pregnancy. This confirms the fact that physiological changes influence Globulin concentrations in Tswana goats.

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Piccione *et al*. (2011) also concluded that the pattern of serum protein concentrations could provide information regarding the level of dehydration, plasma volume expansion and hepatic function occurring during the peri-partum period, including the milking period. Due to high temperatures recorded in the study area, although animals had access to water *ad-libitum,* and heat stress was high during the study period. However, Iradam, (2007); Tharwat *et al*. (2013) and Manat *et al.* (2016); reported a decrease of serum total protein and globulin after the milking period. This could be explained by the fact that during peri-partum, an increase of globulin concentration results in the formation of immunoglobulin (Manat *et al*., 2016) and mostly during the lactation period. Lipogenesis and esterification are reduced, leading to free fatty acid mobilisation by an increase in non-epinephrine and epinephrine secretions.

The results on serum cholesterol did not show significant differences between the three treatment groups Significant decreases observed between weeks 16 and 28, corresponded with stress and increased energy requirements due to pregnancy and lactation. This is an indication that protein supplementation did not have an effect on serum cholesterol concentration in Tswana goats. During energy demand periods, such as pregnancy and lactation, a decrease in protein, albumin and cholesterol could be due also to catabolism of total protein and supply of energy to the mammary gland (Manat *et al*., 2016). Chen *et al.* (1999); and Mellado *et al*. (2008) believe the level of total serum protein corresponds with the survival of kids. This is because the serum total protein and immunoglobulin fractions are necessary for neonate immunity and growth. The results of our study are similar to those of Olafadehan (2015) who observed that total protein and globulin were not significantly influenced by dietary treatments. Furthermore, an increase in the levels of cholesterol while a reduction in serum cholesterol indicates inadequate liver functioning, malnutrition, stress, decreased nutrient intake and hormonal insufficiency. In addition, other studies have shown that high or low cholesterol levels could be indicative of the absence of dyslipidaemia, also known as hypercholesterolemia (Olafadehan *et al.*, 2014).

Dietary protein had a significant effect on urea in weeks 12 and 36. These results do not agree with those reported by Sakha (2008). The results revealed that there was no significant difference reported in urea concentration in goats in the study. However, the lowest value was reported in diet 3 while diets 2 and 3 possessed the highest values. In week 36, high values were reported in diets 1 and 3, while diet 2 had the lowest value of urea. Although significant differences ($p<0.05$) were observed between the three treatment groups of the diets on the

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serum chemistry mentioned above, differences were not attributable to the diet effects since they were within the normal range and were capable of performing their function.

Kaneko (1997) confirmed that cholesterol level is used to diagnose hepatic damage in domestic animals. He further argued that increased cholesterol levels are risk factors for heart diseases, while reduction in serum cholesterol indicates inadequate liver functioning, malnutrition, stress, decreased nutrient intake and hormonal insufficiency. Similar findings were reported by Olafedehan *et al.* (2011), in studies where goats were fed with tannin-rich forage.

4.7 CONCLUSION

The aim of this study was to evaluate the possible effects of different protein dietary supplementations on blood parameters in Tswana goats over time of treatment. The results revealed that serum glucose, albumin and cholesterol were not affected by different concentrations of protein supplemented to the animals. However, it was observed that serum concentrations were affected by different physiological changes such as puberty, pregnancy and lactation for all parameters. In addition, this study revealed significant correlation between serum albuglobulin, urea, total protein, globulin, lipase and triglycerides with protein supplementation and the physiological conditions of goats. It is, therefore, concluded that supplementation of protein influenced blood parameters, which gave an indication of the nutrition and energy status of animals.

The values of all the measured parameters in blood metabolites fell within the normal range of the values reported elsewhere. Incidences of fluctuations in some parameters were observed during this experiment and could have resulted from undetected minor infections, weather extremities in the study area. Furthermore, possible fluctuations reported in this experiment could be due to failure of adaptation of research animals to supplements, resulting in malnutrition. Cases of trauma and stress reported in this study due to theft, might also be possible explanations of the fluctuation of the measured parameters. These findings indicate that there is no impact on different diet levels of protein supplementation on the health status of animals hence, communal farmers could be advised to supplement with treatment group 1 since it contained less nutrients density and could, therefore, be cheaper. However, the effects of protein supplementation on the health status of goats could also explain the effects on reproduction parameters. It is, therefore, imperative to measure the effect of protein

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supplement on reproduction to ensure that no negative effects are imparted on reproduction parameters.

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CHAPTER FIVE: EFFECT OF PROTEIN SUPPLEMENTS ON REPRODUCTIVE PERFORMANCE

5.1 ABSTRACT

This study was conducted to evaluate the impact of protein supplements on the reproductive performance to female goats in semi-arid areas. Observations regarding various reproductive performances were made by following standard procedures (different treatment levels). The level of progesterone in treatment group 2 was significantly higher ($p<0.05$) with the value of 13.5 ng/ml at week 4, while for other groups, no significant effects were observed from weeks 0 up to 20. There was a significant difference ($p<0.05$)in body weight in weeks 20 (6.38 kg), 24 (7.99 kg) and 32 (9.46 kg) for animals in group 1, with week 32 having the highest value of body weights gain compared to other treatment groups. Weight gain increased with age from the beginning of the experiment until week 32, then decreased drastically afterwards because the animals which were pregnant gave birth.

The results provide important information on nutritional status to increase reproductive outputs, mainly through precision supplementation or focus feeding. Feeding of goats with high protein diet significantly ($p<0.0$ 1) increased protein intake (3X maintenance vs 1 X maintenance) compared to low protein treatment. However, no significant ($p>0.05$) difference was observed between low protein and high protein diet for the values of dry matter intake on live birth weight, twinning rate in goats and live weight gain, although there was a tendency for increased live weight gain in goats given the high protein diet. It was recommended that there is need to supplement Tswana goats with high protein diet before giving birth.

5.2 INTRODUCTION

Fluctuations in quality and quantity of forage on small farms in the North West Province are a major constraint for goat production (Department of Agriculture, Forestry and Fisheries, 2012). The production of meat from goats and sheep, plays an important role in the supply of animal protein for the people of South Africa. Goat production in the villages (through the traditional husbandry system) is often characterised by poor growth rate, high mortality and low reproductive rates. Reproduction in goats is described as seasonal; the onset and length of the breeding season is dependent on various factors such as latitude, climate, breed, physiological stage, presence of the male, breeding system and photoperiod (Fatet *et al.*,

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2011). In this situation, the productivity of goat could be increased by controlling diseases through vaccination and anthelmintic drug as well as improving nutrition by either concentrate feeding or the supply of additional forage. . Most farmers rear their goats and sheep using the extensive system in ranged conditions without any supplementation. This system of production causes reduced growth rates and poor reproductive performance, which in turn, results in severe economic loss. Protein is a major limiting nutrient during the dry season. This is compounded by high costs of oil seed cakes that could be used as protein supplements for animals (Webb and Mamabolo, 2010). The problem is aggravated by lack of alternative feeds during the critical dry season. Poor nutrition results in low production and reproductive performance in animals. Undernourished animals are susceptible to disease and parasites and, in extreme cases, animals lose body conditions and could eventually die (Bakunzi *et al*., 2012). The production of meat from goats and sheep, plays an important role in supplying animal protein for people across South Africa. According to Kabir *et al.* (2004), goat production in villages (through the traditionally husbandry system) is often characterised by poor growth rates, high mortality rates and low reproductive system. However, Kochapakdee *et al.* (1994) highlight the importance of concentrate supplementation on growth and productivity of goats and sheep. Supplementing with minimum amounts of protein rich concentrates may increase the level of production at minimum cost. Some authors have reported that grazing alone may not be sufficient for optimising live weight gain and wool production (Etim *et al*., 2014). According to Bakunzi *et al*. (2012), scavengers type of rearing could be supplemented with minimum amounts of protein rich concentrates, thus increasing the level of production at minimum cost. One critical issue regarding kid survival is the nutrition of dams during pregnancy. A study conducted by Laporte-Broux *et al.* (2011) revealed that pregnant goats that are undernourished, give birth to kids with reduced birth weight and heightened mortality rates. Previous literature reported that supplemental food during late pregnancy has shown to reduce kid mortality by improving birth weight and enhancing the immune system, while reducing the incidence of hypothermia (Hashemi *et al.*, 2008; Mahboub *et al.*, 2013). There is little information on supplementation of protein in Tswana goats among communal farmers. The experiment in this study was designed to determine the effects of incremental levels of protein supplementation on reproductive performance and health of goats reared in extensive production systems.

In a review, Leroy *et al.* (2010) attributed lack of oestrus during the early postpartum period in dairy cows to negative energy balance. Moreover, management around the periparturient

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period may affect the overall reproductive status of the recovering female (doe), following birth. Management around this time should aim to assure good postpartum uterine involution, including endometrium repair and cleaning of bacterially contaminated contents (Roche, 2006). According to Ice (2010), improvement in reproductive performance could be achieved with increasing reproductive rate of animals.

According to Abecia *et al*. (2012), reproductive efficiency is directly related to viability of off spring, kidding, kidding interval and length of reproductive cycle. A study conducted by Kunbhar *et al.,* (2016) revealed that goat reproduction could be improved with better management practices and knowledge of normal physiology of reproduction and performance of Tswana goat breeds.

Puberty is the point of sexual development at which the animal becomes capable of reproducing and starts sexual activity. Sexual development is a process of gradual maturation and interaction between the hypothalamus, pituitary and gonads. . According to Bushara and Abu-Nikhaila (2015), puberty is generally considered to be related more to growth and body weight rather than age in tropical goats. Most goats may reach puberty without having achieved an adequate physical growth to support reproduction and first ovulation may not necessarily coincide with first oestrus, depending on nutritional status and breed (Greyling, 2010). Age at first kidding, is expressed as the age when does produce off spring for the first time (Deribe and Taye, 2014). The authors further describe age at first kidding as an important indicator in determining sexual maturity and life time productivity in does; the earlier the doe starts to kid, it will produce more kids in its life time and the longer would be the productive life time period. Kidding marks the beginning of production (Kunbhar *et al*., 2016).

Sheep and goats are very important species due to their biological identity, such as short generation interval, twinning, short growth periods and medium space requirements. Many arid and semi-arid regions in the world have soils and water resources that are too saline for most of the common conventional crop systems. The most ideal approach to evaluate the state of an animal is to assess whether it has the correct weight for its age and physiological stage. On the other hand, it is not always possible to weigh an animal on a scale, e.g. under field conditions, in mountainous areas; at the same time, weighing ewes in advance may induce stress and negatively influence animals (Mahmoud *et al*., 2015). According to

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Mahmoud *et al*. (2015), sheep and goats are considered as productive species, although most breed of both species show yearly reproductive cycles. Very little work has been done to assess the effects of protein supplement on reproduction of Tswana goats. Therefore, the present study was conducted in order to investigate the effects of protein supplementation on reproductive performance.

5.3 MATERIALS AND METHODS

5.3.1 Animals in the study area, experimental design, feeding and management, diet and methods of feeding and live weight

The study was conducted at the North West University Research and Teaching Farm (Molelwane). The location and climatic conditions are described in detail in Chapter 4, Section 4.3.1 The, experimental design, feeding and management, diet and methods of feeding and live weight are described in in Chapter 4, Sections 4.3.2, 4.3.3, 4.3.4 and 4.3.5, respectively.

5.3.2 Reproductive performance

Animals were offered diets for an adaptation period of 10 days, after which they were weighed (initial weight). Animals were weighed bi-monthly and their weight recorded until the end of the trial (for a period of seven months). Age at puberty, gestation period, sex, birth weight of kids and dams were also recorded after parturition. Blood was collected to analyse the level of hormone such as progesterone and to assess reproductive maturity and pregnancy.

5.4 STATISTICAL ANALYSIS

Hormones, growth and reproductive performance data were analysed using the repeated measures on the procedures of SAS (SAS, 2015). Live birth weight, mortality and twinning data were analysed using one way analysis of variance as contained in the Statistical Analysis System (2015) Institute software, according to the following General Linear Model (GLM):

$$Yij=\mu+Di+Eij,$$

Where: Yij=observation of the dependent variable ij;

μ = fixed effect of population mean for the variable;

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D_i = effect of dietary treatment (i = 4); and

E_{ij} = random error associated with observation ij, assumed to be normally and independently distributed.

Statistical significance was declared at p<0.05. When the analysis of variance revealed the existence of significant differences among treatment means, the probability of difference (PDIFF) option in the LSMEANS statement of the GLM procedure of SAS (2015) was used to separate the means. The level of significance was set at p<0.05.

5.5 RESULTS

The aim of this experiment was to assess the impacts of different dietary supplementation on goat production parameters. The results obtained are presented in Table 5.1 and Figure 5.1. Results obtained on the effects of dietary supplementation on reproductive hormones (progesterone) (Table 5.1) showed no significant variations between the three dietary groups (between weeks 1 and 20). The concentrations increased from week 20 and reached the peak at week 28 for animals fed in treatment group 2 in weeks 32 (treatment group 3) and 33 for treatment group 1 (Figure 5.1). Thereafter, the concentrations dropped to reach the lowest levels towards week 35,

Protein supplementation showed on week   the increase of the level of progesterone in the weeks had no significant effects from weeks 0 up to 20. The levels of progesterone in female animals in all diet increased from weeks 20 until 28 and dropped immediately afterwards until week 36, except the level of progesterone in female animals receiving treatment in group 1 where there was an increase in week 32.

It was observed that the level of progesterone (from weeks 0 to week 28) increased gradually and reached the peak around week 28 of age, which correlates with puberty in most goats in treatment group 1. The levels of progesterone reached the peak during weeks 28-32. Progesterone dropped at the end around weeks 34 and 36. The results also showed that dietary group 1 had the highest levels of progesterone at week 32 compared to dietary groups 2 and 3 respectively (121, 3 of 131, 2 ng/ml).

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Table 5.1: Progesterone production in female Tswana goats supplemented with dietary protein (ng/ml)

	Weeks									
Treatment	0	4	8	12	16	20	24	28	32	36
Treatment 1	9.7±1.9	6.3±2.3[a]	11.1±2.0	6.8±1.9	15.1±5.2	7.8±3.2	41.8±9.2	68.4±14.2	37.1±11.3	3.0±1.1
Treatment 2	9.7±2.0	13.5±2.5[b]	8.5±2.1	5.1±2.1	6.5±5.6	17.0±3.4	31.5±10	73.5±15.3	27.5±11.3	1.3±1.2
Treatment 3	9.7±2.2	8.1±2.7[ab]	10.3±2.4	8.0±2.3	7.3±6.1	13.1±3.7	38.4±10	45.5±16.7	45.0±13.8	2.7±1.4

a,b Means with different superscripts on the same column are significantly different ($p<0.05$).

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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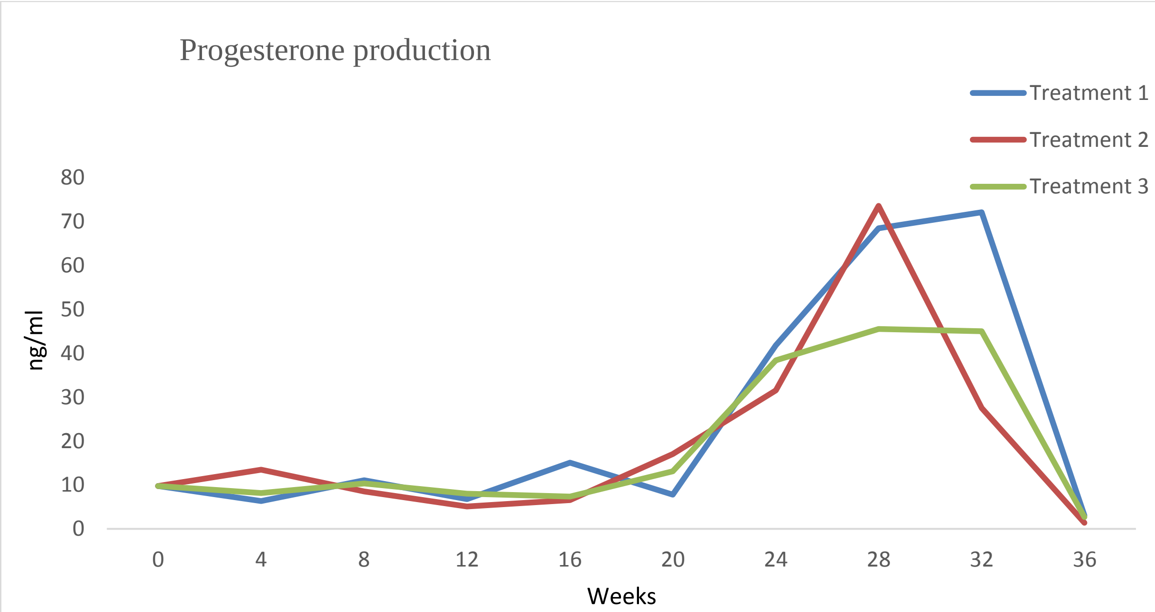

Figure 5.1: Progesterone levels in different groups fed with different dietary protein supplementation

Results obtained in this study also showed different protein treatment supplementations on weight gain in goats (Table 5.2 and Figure 5.2). The results show gain of body weights from weeks 1 to 32 with significant difference ($p<0.05$) between the three groups. Treatment group 1 showed high body weight gain (9.46±0.5 Kg), followed by treatment group 3 (8.36±0.6 Kg) and treatment 2 (7.79±0.5akg) respectively from week 20 to week 36.

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Table 5.2: Body weight gain (Kg) in female Tswana goats supplemented with different dietary protein

	Weeks								
Treatment	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**
Treatment 1	1.33±0.3	3.24±0.4	4.17±0.4	5.17±0.4	6.38±0.4^{b}	7.99±0.5^{b}	9.09±0.6	9.46±0.5^{b}	6.00±1.3^{b}
Treatment 2	1.500±0.3	2.08±0.4	3.01±0.4	3.83±0.4	4.75±0.4^{a}	6.01±0.5^{a}	7.41±0.6	7.79±0.5^{a}	2.50±1.2^{a}
Treatment 3	1.40±0.3	2.36±0.5	3.30±0.5	4.57±0.5	5.36±0.5^{ab}	6.32±0.6^{a}	7.76±0.7	8.36±0.6^{ab}	4.44±1.1^{ab}

a,b Means with different superscripts on the same column are significantly different ($p<0.05$).

Treatment 1= maintenance X1; Treatment 2 = maintenance X 2; Treatment 3 = maintenance X 3

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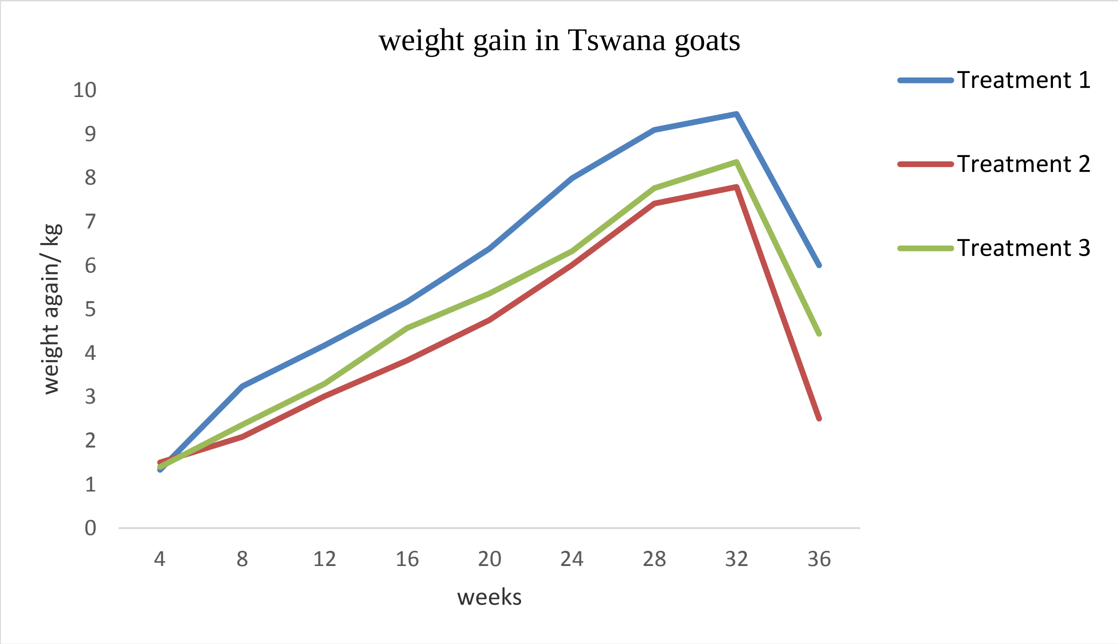

Figure 5.2 Effects on body Weight gain in female Tswana goats supplemented with dietary protein

Protein supplementation did not significantly affect any parameter in as shown in Table 5.3. There was no effect of treatment on mortality and live birth weight of goats. Treatment group 1 had five kid mortalities whereas treatment group 3 experienced only two. However, treatment group 3 had only four goats (twins), while no mortalities were experienced in treatment groups 1 and 2. Feeding of goats with high protein treatment significantly ($P<0.01$) increased protein intake (3X maintenance vs 1 X maintenance) compared to low protein treatment. However, no significant ($P<0.05$) difference was observed between low protein and high protein treatment for the value of dry matter intake on live birth weight, twinning rate in goats and live weight gain, although there was a tendency of increased live weight gain in goats given the higher protein diet. The mortality rate of kids born as twins was lower in treatment group 3 compared to treatment group 1. Goats fed in treatment group 3 did not gain weight since they were pregnant with twins and their energy need was enough from the treatment supplemented with proteins.

Weight gain in different groups was not significantly influenced by the treatment (Table 5.2). However, it was observed that group 1 had the highest weight gain, followed by group 3. Weight gain increased with time and reached its peak at week 32, then dropped because the

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goats gave birth (progesterone decreased after parturition). Weight gain increased with age from the beginning of the experiment until week 32, then decreased drastically afterwards.

Table 5.3: Length of gestation, live birth weight, twinning and mortality of kids fed protein supplementation

	Treatment		
Parameters	Treatment 1	Treatment 2	Treatment 3
Kidding	8 (100%)	7 (87.5%)	12 (150%)
Kid survival	3 (47.5%)	100%	100%
Live birth weight (Kg)	1.79±0.14	1.92±0.11	2.04±0.18
Twinning (%)	0	0	4 (50%)
Length of gestation (days)	151.6±8.4[a]	150.1±7.2[a]	149.2±6.1
Fertility	100	100	100

Treatment1= maintenance X 1; Treatment2 = maintenance X 2; Treatment 3 =maintenance X3

There is likely no statistical differences between the 3 values for Length of gestation to warrant marking with superscript.

5.6 DISCUSSION

A significant difference (P<0.05)) was observed between different groups of goats fed at three different levels. Treatment group 3 had higher body weight gain than treatment group 2, while the maintenance group (Treatment 1) had the highest body weight increase compared to the experimental groups (treatment groups 2 and 3). The results obtained in this study are in line with other studies (Madibela *et al.*, 2002; Kabir *et al.*, 2004; Sahu *et al*., 2013) where a correlation was found between body weight gain of goats and protein supplementation. The body weight gain observed after supplementation is also confirmed by Andesogan *et al*. (2006), who found that feeds of high nutritive value promote high levels of production and that the performance of ruminants is greatly influenced by the amount of nutrients consumed.

However, the reason why the maintenance group (treatment group 1) had gained more body weight than the other two groups (treatment groups 2 and 3) cannot be clearly explained. Bouchard *et al*. (1990), in their study to determine whether there are true differences in

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responses among individuals to long term overfeeding, found that there is a possibility that genotype would be involved in such differences. It is important to indicate that differences in energy efficiency of growth and/or of weight maintenance are most likely to play a role in the susceptible to weight gain (Galgani and Ravussin, 2010). Protein supplementation and body weight gain can also be explained by protein metabolism in which results in large variability in weight change are observed due to energy surplus imposed experimentally or spontaneously (Galgani and Ravussin, 2010). It is important to also indicate that the role of protein in body weight regulation, compared to other macronutrients, consists of different aspects such as satiety, thermogenesis, energy efficiency and body composition, which are partly related to each other (Meza-Herrera *et al*., 2011). In addition, it has been found that protein increases satiety when given iso-energetically. This phenomenon is used in reduced energy intake diets, mainly in the *ad libitum* condition, in which sustained satiety is achieved with sustained absolute protein intake, despite lower energy intake. Also, high protein diets induce high thermogenesis (Westerterp-Plantenga *et al*., 2006), which leads to high energy loss. It was also observed that under conditions of slight body weight regain (aimed at weight maintenance), a high protein diet shows reduced energy efficiency related to the body composition of the body weight regained. This might explain why animals in treatment group 1 gained more weight compared to those in treatment groups 2 and 3 in this study.

No significant differences were observed among different experimental groups regarding weekly body weight gain from weeks 0 to 20. However, a significant body weight gain ($p < 0.05$) was observed from weeks 20 to 32 and then dropped subsequently (Table 5.1). This significant increase was higher in treatment group 3 compared to treatment group 2. The significant increase from week 20 could be explained by the fact that at the time, animals reached their puberty and were pregnant. Body weight drop was observed from week 32 due to parturition.

The results obtained in this study concur with those of Sahu *et al.,* (2013) who reported that the last month of gestation is the period of rapid foetal growth, necessitating supplementation of pregnancy allowance to economy production and minimising reproduction loss in goats These results are also in agreement with those of Acero-Camelo *et al.,* (2008) who showed that supplementation increases the weight of the foetus and more weight loss is obvious for the supplemented groups. The drastic decrease after week 36, in body weight, was due to parturition. Deribe and Taye (2014) reported that the decrease in body weight after birth was due to mobilisation of body reserves, resulting in weight loss.

Reproductive functions in small ruminants are influenced by other extrinsic factors, for instance, social and sexual interactions and nutritional status (Deribe and Taye, 2014). Rahman (2006) reported that progesterone (the hormone responsible for gestation) is the key hormone important for preparing the uterus for implantation and maintaining myometrium quiescence. Poor nutrition results in body weight loss (Tolera *et al*., 2010). The results obtained in this study concur with those of other researchers (Arianmanesh *et al.*, 2011; Mohebbi-Fani et al., 2012; Mutinani et al., 2013 and Xiao 2013). The increase in body weight, through time, could be explained by the fact that protein and energy do improve antioxidant status in animals, which consequently, enhances growth performance and animal production (Meza Herrera *et al.*, 2010).

According to Meza Herrera *et al.* (2010), in ruminants, changes in metabolic hormone plasma concentrations are important signals which inform the reproductive axis about nutrition status of the animal, thus affecting their reproductive performance. The results of this study showed that protein supplementation had no significant effect on the level of progesterone (Table 5.1). The concentrations were stable, varying between 6.8 and 17 ng/ml in all groups from weeks 1 to 20. The increase of progesterone concentration between weeks 20 and 32 corresponded with puberty and pregnancy period of goats, while the dropping of progesterone to low levels, corresponded to an end of pregnancy and kidding periods (Figure 5.2). The results obtained in this study correlate with those of Salve *et al*. (2016). In their study on Sihiro goats, the authors observed low progesterone concentrations and an increase during puberty. It is important to emphasise that progesterone is a pregnancy associated hormone, which increases in concentration during the oestrus cycle around the ovulation period and remains high until the end of pregnancy, allowing the hormone of parturition such as Prostaglandin, cortisone, relaxin and oxytocin to take over (Rahman, 2006).

Although no significant differences were observed in terms of progesterone concentration between the three groups, the results showed that the consumption of additional proteins induced early puberty in treatment groups 3 and 2 (from week 16) compared to treatment group 1 (from week 20) (Figure 5.1). Figure 5.1 shows that there was a difference between treatment groups 2 and 3 with treatment group 3 having higher concentrations. These results

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are in line with those of Titi and Awad (2007) and Yong Zhuo *et al*. (2014), who did not observe any differences in mean plasma progesterone in supplemented goats and gilts. Hong *et al.* (2014) also noted that changes observed in hormonal concentrations could be predicted by changes in secreted hormones and gene expression in the hypothalamus pituitary gonadal axis to high concentration of protein. However, it was observed that the level of progesterone in the control group (Treatment group 1) was higher than in the supplemented groups.

Progesterone concentrations play a fundamental role in determining reproductive efficiency (Mmbengwa *et al.,* 2009). Furthermore, according to Zarkawi and Sonkouti (2009), assessment of progesterone levels during different physiological stages in animals is considered as one of the most important parameters in determining their fertility status. Measurement of progesterone is a widely used technique for monitoring ovarian function and for assessing pregnancy in animals (Terzano *et al.,* 2012). Progesterone concentrations play an important role in determining efficiency of reproduction (Mmbengwa *et al.,* 2009). In goats, maternal serum progesterone concentrations positively correlate with the number of corpus luteum and foetus (Khan and Ludri, 2002).

In this study, all (100%) animals became pregnant and gave birth. These results are in line with those of Madibela *et al.* (2002) and Mugerwa *et al.* (1993) who obtained 81% and 91 % of fertility in goats. This is an indication that protein supplementation has an effect on reproduction. This is also confirmed in this study given the twinning rate (which stood at 50% in the group fed with treatment 3) (Table 5.3). There is a correlation between feed supplement and twinning. These results are in line with those of Titi and Awad (2007) who obtained a twinning rate of 86.67%, 93.33% and 40% at 0, 3 and 5 % fat supplementation. The increase in the rate in treatment group 3 could be explained by the fact that animals, in addition to maintenance, do accumulate energy, which can be used in reproduction. It was also observed that the group (which was fed with treatment 3) (three times maintenance) had 50% twinning.

This study revealed that 50% of female goats in Treatment group 3, gave birth to twins (Table 5.3). The twinning could be explained by the fact that supplemented animals had more active ovaries (Titi and Awad, 2007) and size (Hightshoe *et al*., 1991) hence, more twinning. Other researchers (Lucy *et al.,* 1991; and De Fries *et al.,* 1998) have also explained that fat supplementation provides metabolites that are critical components for stereogenesis, which

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may result in enhanced follicle growth. Fat supplementation may result in increased syntheses of prostaglandin PG2α and, therefore, a better conception rate. This still needs to be debated as not all animals supplemented gave birth to twins.

These results are in line with those of Sahare *et al.*, (2009) who reported twinning among Osmanabadi goats varying from 27.7-76%. However, the results obtained in our study are not in line with those of Titi and Awad (2007) who obtained twins in all supplemented groups of animals. The difference could be due to the fact that the researchers supplemented fat to the animals while in this study, supplemented protein, which has different metabolism pathways, was given to animals. The results are similar with those of Kulkarni *et al*. (2014) who also observed twinning and even triplets among supplemented goats in India. The authors also assumed that twinning could be due also to the effect of supplementation prior to mating, which could have improved the incidence of multiple births. The question that remains unanswered is why other animals (50%) in the same group, under the same conditions, did not have twins.

Kid's live weight at birth showed a significant difference ($p<0.05$) between kids in the three treatment groups (Table 5.3), with kids born from supplemented groups weighing more than those from the control group. Kids from Treatment group 3 weighed more than those from Treatment group two. There is, definitively, a correlation between the body condition of the doe and kids live body weight. Other similar results (Madibela *et al*., 2002; Safari *et al*., 2003; Titi and Awad, 2007) have been reported and confirmed those of this study. Correlation ($P<0.05$) was found between the body weight of the doe and kids live weight at birth. Such results were also observed by Madibela *et al*. (2002) who obtained similar results.

This study recorded kid mortalities of 62.5 and 14.2%, respectively, in Treatment groups 1 and 3 (Table 5.3). Kid mortality reported were mainly due to bacterial infection. Laboratory findings at the North-West University, after post-mortem, revealed that two kids died from Treatment group 1 due to septicaemia. Furthermore, the three kids that died within 24 hours in Treatment group 1, were diagnosed with purulent bronchopneumonia. One of the two goats that aborted in Treatment group 3, had twin foetuses from which *Toxoplasma gondii* and *Staphylococcus ovis* were isolated.

Kid mortalities is a major concern for all farmers as this affects their productivity. Kid mortality was high in the control group compared to Treatment group 3. This contradicts the

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report of Kulkarni *et al*. (2014) who observed that kids born single were much healthier than those born as twins. This is confirmed in this study as the two losses registered in Treatment group 3 were twins born weak. This could be explained by the fact that during pregnancy, the twins share nutrients available and end up with lower birth weight. The higher kid mortality rate observed in Treatment group 1, could also be linked to low birth weight (Kulkarni, 2014). In addition, Ershaduzzaman *et al*. (2007); Kamal-EL-Hassan *et al*. (2009) and Shreedhar (2009) also confirmed that kid live birth weight significantly influenced kid mortality at post-partum. The results confirm the hypothesis that protein supplementation could potentially improve kids survival and growth.

Results obtained in this study (Table 5.3) showed significant correlation ($p<0.05$) between the protein supplementation and the length of gestation, twinning, kidding interval. Animals in Treatment group 3 had the shortest number of gestation days (149.2), with the shortest kidding interval (6.1). The correlation between protein supplementation and gestation length as well as the twinning is an important finding of this study. These results are not in line with those of f Lammoglia *et al.*(1996); Titi and Awad (2007); and Bagumama-Nibasheka *et al.,* (1999) who noted significant differences ($P<0.05$) between treatments and prolonged length of gestation in animals supplemented with fat in ewes. The prolonged length of pregnancy observed by ewes could be due to the alteration of the balance between stimulatory and inhibitory prostaglandins in the parturition process (Baguma *et al*., 1999). It is possible that there was a decrease in estradiol-17â concentrations as well as a decrease of progesterone clearance rate and its conversion into oestrogens at the end of gestation, thus prolonging the gestation period in this study; the long supplementation of protein had an opposite effect as explained earlier. These findings show that early and prolonged supplementation might significantly reduce the length of gestation in goats. However there is a need for more studies with large number of animals to confirm the observations mentioned here.

5.7 CONCLUSION

With regard to the body weight of Tswana goats, no correlation was found between the three treatment groups vis a protein supplementation as the control group gained more weight compared to the two supplemented groups. Stress related to change of feed concentrations could have been the cause of less body weight gain in treatment groups 2 and 3 compared to Treatment group 1, which did not have a change in diet.

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This was one of the major findings of this study, thus the conclusion that supplementation of protein does not necessarily influence the body weight proportionally. In addition, based on other studies, it was concluded that in order to observe proportional body weight increase, supplementation should be done for a longer period to allow the experimental to adjust their metabolism. No significant differences were observed among the three treatment groups with regard to progesterone concentrations over time. However, results obtained in this study showed that there was a correlation between protein supplementation and early puberty in treatment groups 2 and 3.

In this study, goats were grouped into three treatment groups; a control group which received normal maintenance treatment and a group which received protein at maintenance x2 and the other maintenance x3. The results obtained in this study led to the following conclusions:

Kid's live birth weights were found to be proportional to protein supplementation. It was observed that does that received higher amounts of protein also gave birth to heavier kids.

This was in contradiction to the body weight gains of the does as kids from Treatment group 3 had the highest body weight compared to the control group. This led to the conclusion that kids live body weight is not proportional to the body weight of the doe but correlates with feed supplement.

It is also concluded that twinning is influenced by treatment and that protein supplementation effectively influences twinning. However, some of the twins were weak and did not survive.

Finally, the study revealed that survival rate of kids correlated with protein supplementation to the extent that the highest survival rate was observed among kids born from animals supplemented compared to control treatment.

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CHAPTER SIX: GENERAL CONCLUSION

Tswana goats have been identified as one of the most commonly kept breeds in the North West Province, South Africa by rural communities. To improve productivity and develop the farming of this breed in rural areas (which is one of the objectives of the National Development Planning of the Government of South Africa), there is need to assess different sources of feeding and their impact on reproduction and health. The aim of this study was to investigate the effect of protein supplementation on Tswana goats.

The aims and objectives of the study were to:

1. Determine management, production systems and marketing channels for use by farmers in the semi-arid area of Mafikeng for optimum productivity. To achieve this objective, a questionnaire was administered to farmers in the three villages where Tswana goats are mostly kept in Mafikeng Local Municipality. Results obtained showed that the major constraints for farmers were mostly financial constraints, lack of proper training in goat farming and management, ageing of farmers, absence of young farmers in the process, in-breeding within the breed due to land challenges, difficulty in accessing or absence of veterinary services and stock theft. It is concluded and recommended that an incentive be introduced by government and other stakeholders to attract the youth into farming, increase training on goat management, production and access to markets. In addition, there is need to sort out the issue of land distribution to black farmers, which would enable them to do proper management.

2. Determine blood parameters, including reproductive hormones of female Tswana goats. In this study, goats were randomly selected and evenly distributed and supplemented with different concentrations of protein. The impact on blood biochemistry and reproductive hormonal changes were assessed. Results obtained showed that protein supplementation had an effect on progesterone concentration in Tswana goats, thus leading to early puberty in animals given high concentrations of protein. This was one of the major findings of this study. In addition, it was observed that protein supplementation had a significant effect on Albumin, albuglobulin, total protein urea and cholesterol. However, no effects were observed on glucose, lipase

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and triglyceride levels. It was also observed that physiological changes in the life of the animal significantly affected all the biochemical parameters of the animal. This was also a major finding of this study. It is, therefore, concluded that blood biochemistry parameters would clearly give the nutritional status of the animal and that protein supplementation in animals would be beneficial for the animal if done for a long period to allow the animal to adapt and respond to the changes.

3. Determine the effect of incremental levels of protein supplementation on reproductive and growth performance and health of female Tswana goats. To achieve this aim, supplemented animals were weighed regularly, during puberty and kidding. The weight and number of offspring were also recorded. The results revealed that high protein supplementation influenced the weight of Tswana goats and also during puberty and kidding, the weight and number of kids.

Productivity of this breed has been one of the challenges faced by farmers in these areas. Shortage of good quality feed, especially during the long dry season in tropical and subtropical areas, has increased the need to provide supplementary feed to sustain livestock production, particularly goats. Incorporating maize and soybean in the diets of goats fed with low quality roughages could lead to better performance. It is concluded that improved feeding with better management could ensure an improvement in reproductive performance of Tswana goats. Furthermore, in order to optimise production in the goat industry, management programmes should be implemented to improve the reproductive aspects of goats since they are the source of animal protein and to alleviate the need in developing countries, which helps in the social upliftment of rural poor communities.

Apart from research, several recommendations could be made to enhance goat productivity in rural areas of the North West Province. The major aspects are feeding management, training of farmers, marketing management and management of goats. Training of farmers requires the cooperation of the Department of Agriculture, research institutions, universities and other stake holders. The training of extension officers, who will, in turn, train communal goat farmers, could go a long way in realising and exploiting the potential of goat production. There is need to improve marketing management and policies in most countries in Southern Africa. Resource-poor farmers need to form co-operatives and pool their animals together prior to marketing. The main challenge with marketing of goats in communal areas is the dissemination of information on prices and market requirements. Provision of premium

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prices for animals in better conditions will motivate farmers to invest in improved animal feed and management technologies. There is also a need to establish more formal markets to enable farmers to sell their products.

The study still needs to be extended to educate farmers that cost benefit analysis is needed even where farmers have crop residues in their farms. To optimise the productive potential of Tswana goats, it is important that the reproductive management programme be implemented for the improvement of reproductive aspects of goats.

It is, therefore, concluded that improved feeding with better management could ensure the improvement of reproductive performances of Tswana goats. Thus, the adoption of improved supplementary feeding practices by communal farmers could be enhanced by creating awareness among farmers with regard to the rearing of goats through on-farm trials and participatory approaches. Future studies on supplementation feeding by goat farmers in the study areas could be conducted to assess the impact of supplementary protein on growth performance and reproductive health of Tswana goats reared in extensive production systems

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6.1 APPENDICES

Appendix 1: Peer-reviewed articles and papers published and to be produced from the thesis

1. Survey of production systems, management and marketing strategies for Tswana goats in semi-arid areas around Mafikeng, North West Province (**published**). *Journal of human ecology,* 56 (1; 2): 139-142.
2. 2 Impact of different dietary protein levels on goat minerals and blood parameters (**in progress**).
3. 3 Impact of protein supplements on reproduction (**in progress**)

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Appendix 2: Questionnaire

Survey of production systems, management and marketing strategies of Tswana goats

A. HOUSEHOLD GENERAL INFORMATION

1. Interviewee.. 2. Head of household...................................

3. Village..

4.Level of education	
1.Tertiary education	
2.Completed high school	
3.Completed primary school	
4.No education	
6. Age	
1. ≤ 30	
2. 31-40	
3. 41-50	
4. 51-60	
5. 61-70	
6. > 70	
8. Age (years)	
1. Crop	
2. Grazing	
3. Total size	
4. 51-60	
5. 61-70	
6. > 70	

5. Gender	
1.Male	
2.Female	

7. **Number of people residing in household**	
1. Males	
2. Females	
3. Children (<15 years)	

9. Land ownership	
1. Own	
2. Lease	
3. Communal other (specify)	

10. **Livestock activity**	
Is livestock the major activity on your farm?	

11. Livestock kept	
(*Enter numbers in first column*)	Most important species (rank up

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Yes	
No	

	to 3)
1.Cattle	
2. Sheep	
3. Goats	
4. Chickens	
5.Donkeys	
6. Pigs	

12. Total annual income (category)	
1. R 0 – 10,000	
2. R 10,000 – 40,000	
3. R 40,000 – 80,000	
4. R 80,000 - 120,000	
5. R 120,000 – R250,000	
6. > R 250,000	

13. Income generated from livestock annually	
1. R 0 – 10,000	
2. R 10,000 – 40,000	
3. R 40,000 – 80,000	
4. R 80,000 - 120,000	
5. R 10,000 – 40,000	
6. > R 250,000	

B. GOAT PRODUCTION	
1. System of production	
1. Industrial/intensive	
2. Semi-intensive	
3. Extensive/pastoral	
4. Free range/backyard	
5. Others (specify)	

2. Composition of herd	
1.Bucks	
2. Does	
3. Pubertal female goats	
4. Pubertal male goats	
5. Kids	
6. Castrates	

3. Purpose of keeping goats	
1. Meat	
2. Milk	

4. Members of household who own or keep goats	
1. Head	
2. Spouse	

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3. Wool	
4. Stud breeding	
5. Manure	
6. Investment	
7. Cash from sales	
8. Ceremonies	
9. Cultural	
10.Other (specify)	

3. Sons	
4. Daughters	
5. Others	

5. Goat breeds	
1. Tswana goats	
2. Indigenous goats	
3. Mixed breed	
4. Synthetic breed	
5. Others (specify)	

	6. Goat feed resources (do you use the following resources and in which season?)			
	Summer	Autumn	Winter	Spring
1. Natural pasture				
2. Planted pastures				
3. Crop residues				
4. Milling by products				
5. Oilseed by-products				
6. Forage trees				
7.Bought in concentrates				
8. Mineral supplements				
9. Others (specify)				

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7. Grazing/feeding	
1.Herded	
2. Paddock	
3. Tethered	
4. Stall	
5. Yard	
6. Free grazing	
7. Others (specify)	

8.Housing	
1. Kraal	
2. Stall/shed	
3. Yard	
4. None	

9. Supplementation regime	
(Tick as appropriate)	
1. Roughage/crop residue	
2. Minerals (salts) / vitamins	
3. Bought-in feed / concentrates	
4. None	
5.Other (specify)	

10 Water sources for goats	
1. Animals go to the water	
2. Water is fetched/provided	
3. Both	

11. Access to veterinary services	
1. Government veterinarian	
2. Private veterinarian	
3. Veterinary drug supplier	
4. Extension services	
5. None	

12. Prevalent diseases	

13. Vaccinations/preventive treatments given		14. Animal entries and exits per year		

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		Entries	Exits	

15. In your opinion, what are the major constraints to goat production (rank 1, most important to least important)

1..............................

2...............................

3.............................

4..............................

5...............................

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Appendix 3: Curriculum Vitae

1. General information

Title, name and surname:	Mrs Mpho Sylvia Tsheole
Date of birth:	1974-04-09
Citizenship:	South African
Residential address:	10285, Setumo Park, Mahikeng, 2745
Postal address:	P.O. BOX 23804, Mahikeng, 2745
Professional registrations:	South African Veterinary Council

2. Contact details

Organisation where based:	North-West University (Mahikeng Campus)
Faculty or School:	Faculty of Natural and Agricultural Sciences
Department:	Animal Health
Work telephone number	018 389 2731
Work fax number	018 389 2748
Cell phone number:	073 5727 436
Email address:	Mpho.tsheole@nwu.ac.za
Website address:	www.nwu.ac.za
Work postal address:	Private Bag X2046, Mmabatho, 2735
Work physical address:	Cnr Dr Albert Luthuli and University Drive, Mmabatho, 2735

3. Qualifications (from highest qualification)

Qualification type:	Master of Science in Agriculture
Field of study:	Animal Health
Institution:	North-West University (Mafikeng Campus)
Year obtained:	2013

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Qualification type:	Honours Bachelor of Science in Agriculture
Field of study:	Animal Health
Institution:	North-West University (Mafikeng Campus)
Year obtained:	2011

Qualification type:	Bachelor of Science in Agriculture
Field of study:	Animal Health
Institution:	North-West University (Mafikeng Campus)
Year obtained:	2006

4. Other qualifications

Research Showcase Awards – MSc. degree ,2013	Certificate of Achievement
ICP-OES COURSE- 7 September 2014	Certificate
Separation Scientific SA (PTY) Ltd- Atomic Absorption Spectrometry Training Course-AAS Techniques, Operation and Practical Aspects-20 May 2014	Certificate
Attended world Buiatrics Congress in Dublin and presented a paper (3-8 July 2016) **Attended an Equine Welfare workshop in Mafikeng (North-West University) 2017** **Attended the 50th Sasas Congress in Port Elizabeth and presented a paper (18-21 September 2017)** **Attended a course session on Tick Identification at ARC- Onderstepoort Veterinary Research (3-6 October 2017)**	Certificate Certificate

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Publications	1. [1]Mpho Tsheole, Gloria Kgobe, Mulunda Mwanza, Lebogang Motsei, Frank Bakunzi, 2016. Effect of **Phosphorus and Calcium supplementation on growth performance of communally grazed goats in semi-arid areas.** *Journal of Food, Agriculture & Environment* 15 (2): 68-73., 2017. 2. [1]Mpho Tsheole, [2]Victor Mlambo, [1]Mulunda Mwanza, 2017. **A survey of production systems, management and marketing strategies for Tswana goats in semi-arid areas around Mafikeng, North West Province,** *Journal of human ecology* 56 (1; 2): 139-142. 2016. [1]Mpho Tsheole and [2]Mulunda Mwanza: **Impact of protein supplements on reproduction of Tswana Goats in Semi-Arid Area of North West Province of South Africa performance**. *Journal of Agricultural Science and Food Technology, 5(3): 2019*.