UTILIZATION OF CROP RESIDUES AND AGRO – INDUSTRIAL BY PRODUCTS BY TSWANA SHEEP FED VARYING ENERGY SOURCES AND MINERALS

By

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A dissertation submitted in partial fulfillment for Master of Science Degree in Animal Science (Animal Nutrition)

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DECLARATIONS

I declare that the dissertation was submitted by me for the Master of Science Degree (Animal Science) at Botswana University of Agriculture and Natural Resources, is my own independent work and has not been submitted previously at another university.

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SEPTEMBER 2021

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CHAPTER ONE

1.0 General Abstract

Two experiments were conducted at Botswana University of Agriculture and Natural Resources, Sebele. In Experiment 1, twenty-five Tswana sheep were used in 3 x 2 factorial arrangements in a Complete Randomized Design to determine the effect of substituting sorghum bran with either sorghum stover or millet stover on performance of Tswana sheep. The experimental diets fed were: T1= 40% Cenchrus hay + 30% sorghum bran + 28% sunflower meal + 2% mineral premix*, T2= 40% sorghum stover + 30% sorghum bran* + 28% sunflower meal + 2% mineral premix *, T3 = 50% sorghum stover + 20% sorghum bran* + 28% sunflower meal + 2% mineral premix*, T4= 40% millet stover + 30% sorghum bran* + 28% sunflower meal + 2% mineral premix*, T5= 50% millet stover + 20% sorghum bran* + 28% sunflower meal + 2% mineral premix. *The results indicated insignificant differences (p>0.05) in all the treatments on the feed intake (FI), weight gain (WG), final weight (FW), average daily gain (ADG) and feed conversion ratio (FCR) of Tswana sheep. In Experiment 2, thirty-six Tswana sheep were used in a 3 x 2 factorial arrangement in a complete randomized design to determine the effect of minerals on performance, carcass characteristics and blood and liver mineral concentration. The experimental diets were T1= Cenchrus hay (50%) + supplements with minerals(50%) , T2 = Cenchrus hay (50%) + supplements without minerals (50%) , T3 = Sorghum Stover (50%) + supplements with minerals (50%), T4= Sorghum Stover (50%) + supplements without minerals (50%) , T5 = Millet Stover (50%) + supplements with minerals (50%) , T6 = Millet Stover (50%) + supplements without minerals (50%) . The results indicated insignificant (p>0.05)treatment effects on FI, WG, FW, ADG, FCR, carcass weight, chuck blade weight, flank weight, leg weight, neck weight, breast weight and femur length of Tswana sheep. The data showed that Tswana sheep fed diets T1, T3 and T5 differed (p<0.05) significantly from those fed diets T2, T4 and T6 in both blood and liver Ca, P, Mg and Na concentrations. The result also showed that Tswana sheep fed diets T1, T3 and T5 differed from those fed diets T2, T4 and T6 in effect on the blood and liver Cu, Fe, Zn and Mn concentrations. In general, it was concluded that millet and sorghum stover can positively substitute sorghum bran without any significant effect on performance characteristic of Tswana sheep. Minerals supplementation was also emphasised to be included in Tswana sheep diet in order to avert minerals deficiencies.*

Key words: Agro-industrial, Crop residues, Utilisation, Tswana sheep

1.1: General Introduction

Agriculture contributes 2.2% of the total Gross Domestic Product (GDP) of Botswana (Statistic Botswana, 2015). An estimated 80% of Agriculture's share comes from livestock production, mainly beef. The ratio of small ruminant to cattle is about 44%. As in many developing countries, livestock plays many roles in the socio-cultural lives of the people of Botswana including provision of cash, food, draft power and as well as poverty alleviation (BARC, 2010). The current sheep population in Botswana is 227247 with 18690 sheep holdings. Ninety-three per cent of these are found in traditional farms while the rest are in commercial farms (Statistics Botswana, 2015). Eighty-four per cent of the sheep in Botswana are pure Tswana and its crosses, while the remaining sixteen per cent are Karakul and its crosses (Nsoso and Madimabe, 2004). Other sheep breed found in Botswana include: Dorper, Blackhead Persian and Namanqua Africander. The rams of these are used to crossbreed the Tswana or Karakul. Tswana sheep is found all over Botswana, has a root fat tail and a coat with mixture of hair and coarse wool.

The prevailing climate in Botswana is arid to semi-arid with mean annual rainfall varying between 650mm in the North East to less than 250mm in the South West. The rainfall amount is low and its distribution pattern is often erratic (Parida, 2008). In spite of this, Botswana has a wealth of natural and agricultural resources. Available forage resources comprise mostly rangelands with very little cultivated pastures (Dougil *et al.*, 2016). However, lack of adequate nutrition, especially during the dry-season, has been a major constraint to sustainable livestock production in small-scale farm conditions. Considerable quantities of crop residues are produced and can be harvested for dry season feeding of livestock. On small farms, the nutritional quality of crop residue-based diets can be improved by either providing a high-quality legume fodder (high protein) and/ or combining with other available Agro-industrial by-products.

Sheep like other types of ruminant livestock in Botswana are kept mainly under the subsistence production system with only 6.72 percent kept on commercial farms (BARC 2010) Under this type of production/management system (subsistence), the animals are left to graze on rangelands of the communal areas which often are over-grazed due to uncontrolled grazing (FAO, 2014) thus meeting the nutrient requirements of these animals becomes difficult. According to FAO, 2014), natural pasture is the major feed resource for ruminant animals in Botswana. Forages are usually the sole source of energy for sheep and energy is the most common nutritional deficiency in ewes (Dougil *et al.*, 2016). Concentrate supplements like Lucerne to augment this forage-based diet are judged expensive by farmers and not readily available (Tsopito, 2010). Furthermore, available forages in communal rangelands do not maintain their quality and quantity year-round; there is usually a sharp decline especially during the winter season when their nutritive values are drastically reduced aggravating feeding problems of ruminant livestock. As a result of these dry-season adverse conditions, animals lose weight, body condition and have low milk yields, low conception rates and increased lamb mortalities, all of which culminate into heavy economic loses to the small holder farmers.

Crop residues are roughages that become available as livestock feeds after crops have been harvested. They are distinct from agricultural by-products (such as bran, oil cake etc) which are generated when crops have been processed. Residues are usually grouped by crop type-cereals, grain legume, roots, and tuber (Nordblom and Shomo 1995). The supply of crop residue is a function of the proportion of land used for cropping and of the edible feed yield per unit of land. Where consumable feed from crop residues exceeds grazing from natural pastures (expressed in tonnes of dry matter per hectare, t DM ha^{-1}), expansion of cropland has overall effect on feed supply (Statistics Botswana, 2015).

Maize and Sorghum are the major cereal crops in Botswana, followed by Millet and Groundnut, consequently, they generate considerable amount of grain and residues. While the grains are well utilized by human and other monogastrics, the residues are not maximally utilized by the ruminants which have the digestive system capable of extracting and utilizing nutrients from these crop residues. In 2014 Botswana produced about 46 258 metric tonnes of Agro-industrial by-products of which a reasonable portion was not utilized. And within the same year (2014) total area harvested was about 161 245 hectares (Statistics Botswana, 2015).

Ruminants just like the monogastrics need all the various classes of nutrient (energy, protein, vitamins, minerals and water) for proper development, reproduction and production (Tsopito, 2010). However, several factors like breed, genetic selection, age, management conditions, properly balanced feed mixtures and primarily, the quality and amount of protein in relation to energy/net energy, influence the amounts of protein and energy used by the animals for 1 kg weight gain. So, we can say that protein and energy resources are the fundamental factors limiting the size of animal production in each country and regions of the world (Szebiotko, 2003). Since the digestive system is a major determinant of the nutrient need of an animal, the ruminant animal with abundant microbes in its rumen is able to utilize fibre to generate its energy needs. While the monogastrics competes with human over grains which are becoming increasingly scarce and expensive, the ruminant can utilize this tough fibrous feed by converting them to useful animal products (Liao, 2015).

There are constraints (such as the fibrous nature of most crop residues, mineral deficiencies, low and variable digestibility, low bulk density) to utilizing crop residues but there are appropriate and relevant interventions for utilizing them in rations of ruminant animals. These include; treatments with acids or alkalis (urea) to improve digestibility, supplementation with by-pass protein, supplementation with rumen nutrients, pellet feed to increase bulk and chopping or macerating tough fibrous materials to improve chewing (Leng 2008).

1.1.1: Justification

Inadequacies in quantity and quality (especially during winter) of forage results in poor performance below the potential genetic capabilities of animals. As a consequence, farmers often experience low off-takes from their livestock. Poor knowledge concerning strategies of utilization and incorporation of these resources into the ration of animals has led to their inefficient use. Uncontrolled utilization of the range resources in the communal land has led to over-grazing and denudation of rangelands such that there is an imbalance between the growing ruminant population and available range resources. Consequently, farmers may inevitably have to use agro-industrial by-products to augment the disappearing range resources in order to meet the nutrient requirement of their livestock.

1.2: Specific objectives

The objectives of the study were to:

1. To determine the effect of dietary energy sources on feed intake, average daily gain, and feed conversion ratio of Tswana sheep when fed sorghum stover or millet stover as basal diet, supplemented with protein, vitamin and mineral premix.
2. To determine the effect of dietary mineral offered on feed intake, average daily gain, feed conversion ratio, carcass characteristics, blood and liver mineral concentration of Tswana sheep when fed basal diet of stover and supplemented with protein, mineral and vitamin premix.

1.2.1: Hypothesis

H_O: Supplementation of sorghum and millet stover diets with protein, mineral and vitamin premix does not improve intake and performance of Tswana sheep.

H_A: Supplementation of sorghum and millet stover diets with protein, mineral and vitamin premix improves intake and performance of Tswana sheep.

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1: Introduction

At independence of Botswana in 1966, agriculture was the predominant occupation of majority of the people contributing about 40% to Gross Domestic Product. This role however has declined due to cyclic droughts. About 70% of the population lives in the rural areas and are dependent on agricultural activities for their livelihood. Traditional holdings cover 70% of Botswana total land area. Two - thirds of traditional farmers engage in mixed farming with individual landholding and communal grazing of livestock. Large numbers of animals degrade pastures especially in winter where natural pasture is reduced. This results not only in inadequate feed but also in poorer quality pastures each year. Since supplementary feeding is hardly done due to the cost involved, consequently meeting the nutrient requirements of the animals becomes difficult.

2.2: Livestock production in Botswana

The Ministry of Agriculture annual survey (2012) results depicted a declining trend in agricultural production both in the livestock and crop sub-sectors. The poor performance of the agricultural sector was attributed mainly to poor rains and the outbreaks of pests and diseases (CSO, 2014). These compromised the effectiveness of Government assistance programs such as the Integrated Support Programme for Arable Agriculture Development (ISPAAD) and the Livestock Management and Infrastructure Development (LIMID) that have since been introduced to revitalize the sector. Results from the 2012 survey indicated that livestock population between the 2011 and 2012 agricultural seasons decreased as follows; cattle population dropped by (12%), goats by11.1% and sheep by 0.7% due to insufficient pastures. According to production indicators, cattle mortality experienced a significant increase from 6.0 % in 2011 to 9.1 % in 2012, reversing modest gains in the birth rate from 52.6 % to 53.1 % during the same period (MoA, 2012). Off-take rate also increased slightly from 6.9 to 7.4 % under the reporting period. The increase in the off-take rate indicated that farmers were applying coping strategies (CSO, 2014). The birth rate of goats was unchanged from 41.5 % to 41.4 % during the period under review, mortality rate declined from 24.1 % to 21.9 % and off-take increased from 5.8 to 6.1 %. Sheep experienced a slight increase in birth rate from 32.8 % to 33.5 %, while the mortality rate dropped modestly from 16.4 to 14.6 % and off-take from 5.9 to 4.9 %. Even though mortality rates of small-stock showed a decline, they are still high compared to cattle mortality rates. According to the survey results, in 2012 cattle population was concentrated most in the Central Region and least in the Maun Region. Male farmers, during the 2012 agricultural season, dominated cattle ownership with a share of 74.6 % of the national herd compared to their female counterparts who only had a share of 25.4 %. Male farmers were also the majority owners of goats (64.1 %) and sheep (66.7 %).

2.3: Crop Production in Botswana

The picture portrayed by the 2012 survey results is worrisome in respect of production of cereals and cash crops. Between the 2011 and 2012 agricultural seasons, production of sorghum fell from 32,591 metric tons to 24,021 metric tons; maize production plummeted from 35,322 metric tons to 7,677 metric tons while millet registered a decrease from 2,511 metric tons to 1,959 metric tons. Production of groundnuts achieved only 200 metric tons in 2012 compared to 833 metric tons in 2011. Likewise, sunflower production dropped to 6,000 metric tons in 2012 from 15,837 metric tons in 2011. In terms of yield per hectare, the traditional sector registered a decrease except for sorghum. The poor performance of the arable sector in 2012 is attributed mainly to extreme weather conditions. Commercial farmers achieved better yields compared to their counterparts in the traditional sector.

Table 2.1: Area planted (Hectares) by cereal crops in the regions of Botswana for 2012

REGION	SORGHUM	MAIZE	MILLET
Southern	6375	48215	-
Gaborone	9764	46627	350
Central	21638	23163	1398
Francistown	12280	17556	5622
Maun	1643	4406	2975
Western	94	971	-
TOTAL	51795	140937	10344

Source: Statistics Botswana (2015)

Table 2.2: Cereal crops yield in the regions of Botswana (Total Production in Metric Tonnes) for 2012

REGION	SORGHUM	MAIZE	MILLET
Southern	4296	29583	-
Gaborone	3399	11343	160
Central	8371	6755	632
Francistown	7362	5977	3925
Maun	802	1689	2229
Western	-	389	-
TOTAL	24231	55735	6945

Source: Statistics Botswana (2015).

2.4: Production of Crop Residues

Crop residues are the part of plants left in the field after the crops have been harvested. Crop residues are good sources of nutrients and organic material added to the soil. While a lot of crop residues are generated after harvesting cereal crops and legumes, a lot of these have not been maximally utilized by smallholder farmers. Animals usually are allowed to get into the field to graze on them and the bulk is trampled on. In addition to grazing, straws from harvested crops are collected off the field and fed to animals in pen or used to prepare beddings. Furthermore, smallholder farmers lack the strategies of incorporating these crop residues into their livestock feed.

A global review on the annual yields of fibrous crop by-products was done at FAO headquarters. The study involved some 100 commodities, 212 countries and a period covering the years from 1970 to 1981. The results of the study have been published from the regional and socio-economic group point of view (Kossila 1983). In North and Central America, Europe, and South America the size of livestock population is similar but north and Central America has a very high fibrous crop residue. Quantitatively taken in Africa and USSR the fibrous crop residue situation is quite similar to each other. In Oceania, on the other hand, very little residues are produced.

The World's “grain storehouse” North and Central America produced 6.66 tonnes of fibrous crop residues per LU of grass eaters in 1981. Europe and Asia ranked the second in this respect with some 3.5 tonnes/LU. Europe, however, has a very large herbivores population – (33.7%) of the total LU numbers, compared to Asia's 17.1%. USSR produced 2.94 tonnes of fibrous crop residues per LU of herbivores. Like Europe, USSR also has a high herbivores population (26.1% of total LU number).

In 1981, Africa carried about 12% of the world's herbivores population and it produced some 343 million metric tonnes of DM from crop residues which accounted for 7.7% of the world total. 68.8% of the African crop residues were derived from cereals, 12% from oil plants and pulses, 4.9% from sugarcane etc. Africa has clearly defined areas with rather definite preferences for certain cereals. Maize is prevalent in South-East Africa, in Egypt and in a few South-Western countries (Ivory Coast, Ghana and Benin). Millet and sorghum are prevalent in Middle and West Africa. Wheat is popular in North Africa. Rice is preferred in several countries on the South West coast and in the East Coast Islands (Comoros, Madagascar). Two countries, i.e. Reunion and Mauritius are specialized primarily in sugarcane production.

The quantities of DM from fibrous crop residues produced per LU of herbivores in different African countries in 1981shows that there is a definite belt of countries beginning from the South East coast (Mozambique) and extending to the South West African coast line, which have produced over 2 tonnes/LU of grass eaters of fibrous crop residues. On the other hand, North African countries (with exception of Egypt and Tunisia) as well as Botswana and Namibia in the South had very low crop residue figures. Such factors as quantity of rainfall, soil conditions, amount of water available for livestock, animal health problems (tsetse) play a significant role as far as the above figures are concerned

2.5: **Composition of Crop residues**

Leng (2008) stated that crop residues have a generally low crude protein content (3.3 to 13.3% DM) and deficient in fermentable energy due to low organic matter digestibility and low in minerals. Abundant crop residues are available in different parts of the world; about 35 million tons of straw are produced annually in Australia which could feed 7 million cattle, however because of the inherent limitations due to their nutrient composition, strategies for utilizing them in diets of ruminant animals become pertinent. Crop residue is made up of five plant tissues namely: (1) the vascular bundle which contains phloem and xylem cells (2) parenchyma which surrounds the vascular bundle (3) sclerenchyma which links the vascular bundles with the epidermis (4) mesophyll cells which is found between the vascular bundle and the epidermis

(5) epidermal layer covered by the cuticle. The various tissue parts are digested in the rumen to different levels. Generally, tissue digestion by rumen microbes starts with mesophyll and phloem followed by the epidermis and parenchyma then the sclerenchyma. The final parts digested are the lignified vascular tissues. Unlike the conventional feeds, the nutritive value of crop residues is dictated by its level of tissue digestion (Minson, 1990). The cells are made up of cell contents and cell walls. Mostly found in the cell contents are the CP, soluble carbohydrates, organic acids, fats and ash while the cell wall is made up of cellulose hemicellulose, lignin, silica and cutin. The cell wall of most crop residues accounts for 60-80% of the dry matter (DM) (Tingshuang *et al*., 2002).

2.6: Production and Utilization of Crop residues

The largest portion of crop residues produced in Sub-Saharan Africa is cereals (236 million tons) which constitute about 70 percent of the total crop residues generated. These residues are from maize, millet and sorghum (Reed and Goe, 1989). In Botswana, about 2 million metric tons of cereal crops (sorghum, maize and millet) are produced annually which could serve as feed resource to the ruminant (FAO, 2014). De Leeuw (1997) stated that there are two kinds of ratio that can be used to link grain and crop residue yield; one being grain yield divided by an agreed factor expressing the harvest index or proportion of grain to total above- ground biomass. The other being a relationship between the proportions of land cultivated combined with yield estimates for the grains, tuber and so on for the major crops. Therefore, the more the size of the cultivated area of a crop, the more the crop residue obtained from that crop (Nordblom and Shomo 1995).

Crop residues which could serve as feed resource are usually left to be trampled by livestock or ploughed under and these could be utilized for feed if they were harvested and preserved after the grains are harvested. This will ensure better crop residue yield and nutritive value (Mosimanyana, 1983). Kabatange and Kitalyi (1989) observed from a diagnostic survey that there is underutilization and inefficient use of the crop residues in Tanzania. This they observed could be due to the bulky nature of these residues as well as the cost involved in harvesting, collection, handling, and transportation and storage methods. Furthermore, they stated the need for development of technological packages on proper use of this feed resource. In Senegal, cereal straws represent an important source of energy; however, low concentrations of nitrogen Kabatange and Kitalyi (1989), minerals and digestible energy make supplementation inevitable if they are to be fed to animals. Cereal straw can be supplemented by peanut cake, cottonseed, sorghum, millet, and rice bran. Treatment of straws with urea (NPN source) is the most promising alternative solution to enhancing straws utilization by ruminants (Fall *et al.,* 1989).

Ogundola (1989), conducted an experiment to determine the growth characteristics of growing calves when replacing maize with wheat offal and brewer's dry grains on dry matter digestibility, metabolism and rumen degradability of the ration fed to calves. Their results indicated no significance on dry matter intake, total digestible nutrients and energy intakes of growing calves (Ogundola, 1989). According to a study by Gebrehiwot and Mohammed (1989), the yield and quality of crop residues could be tremendously improved by improving agronomic practices and selecting good varieties of forage crops. However, under-sowing of wheat with forage crops resulted in no change in reduction of grain yield but resulted in increasing production of straw and forages which improved feed intake and digestibility of the ration fed to growing calves (Gebrehiwot and Mohammed, 1989).

Olayiwola and Olorunju, (2009) emphasised that crop residues such as sorghum stover showed the potential of improving live weight gain of cattle. Moreover, they further mentioned that protein and mineral premix supplementation of sorghum stover produced desirable results when fed to cattle. However, it was emphasised that animals that are kept under intensive or semi-intensive management system performed better when fed this type of rations (Olayiwola and Olorunju, 2009). Mohammed *et al*. (1989) when conducting a study with beef cattle found that Sorghum Stover could be incorporated in concentrate finishing rations of beef cattle to levels as high as 45% without any adverse effect on performance. This traditional system of feeding concentrate mix *ad lib* by feedloters was observed as wasteful since as much as almost half of it could be replaced by Sorghum Stover (Mohammed *et al*., 1989).

2.7: Leguminous crop residues

FAO (2014) reported that the production of legumes in Botswana is primarily done on a commercial basis; therefore, these crops do not play a significant role in small-scale livestock production systems. Small-scale producers who grow legumes utilize them by grazing their livestock after harvest, while the stubble is ploughed back. In Cameroon, Njwe and Godwe, (1989) conducted a study to compare feed utilization and live weight gain of West Africa dwarf Sheep fed treated dry soya bean pods and Napier grass supplemented with soya bean flour and sodium hydroxide. Their results showed that sheep fed Napier grass significantly had higher feed intake than sheep fed soya bean pods diets. Moreover, live weight was similar for sheep when fed Napier grass supplemented with soya bean meal (Njwe and Godwe, 1989).

Yiala (1990) showed that in a study where different legume crop residues were used to supplement a rice straw and rice bran basal ration of Sheep, live weight of supplemented animals did not differ in live weight gain between the supplemented animals and the control. Feed intake differences were highly significant between the groups with increasing intake and crop residues reducing it. According to Yiala, (1990), variation in height of withers, heart girth and scapula-ischial showed no significant differences between treatments. Cottonseed cake was found to be the most effective supplement in terms of both intakes of crop residue and live weight gain. Ngwa and Tawah (1992) showed increases in apparent digestibility of the dry matter due to inclusion of cotton seed cake in fibrous diets.

2.8: Treatments / processing of crop residues for livestock feed

The poor nutritive value of crop residues has been reported by Aganga and Nsinamwa (1997) to have an influence on the content of lignin which basically hinders the digestion of cellulose and hemicelluloses by the enzyme in the animal body metabolism (Aganga and Nsinamwa, 1997). Furthermore, these crop residues can be modified to improve their digestibility either physically, biologically or chemically (Aganga and Nsinamwa, 1997). According to Lardy (2008), ammoniation of crop residues can double or triple crude protein levels of crop residues such as straw and corn stalk and also have the potential of increasing digestibility of the ration by 10 to 30%. Moreover, it can also increase feed intake by 15 to 20 % percent. Trace minerals such as phosphorus and vitamin A can be added to diet rations whenever ammoniated residues are fed (Lardy, 2008). According to Aganga and Nsinamwa (1997) chemical treatment particularly with alkali (sodium hydroxide) and urea can be used to improve the nutritional composition of crop residues. This can be achieved by the disruption of the cell wall when solubilising the fibre components (hemicelluloses, cellulose and lignin), hydrolysis of uranic and acetic acid (Aganga and Nsinamwa, 1997).

2.9: Constraints of crop residues and agro-industrial by-products utilization

Low nutritive value of crop residues and the need for supplementation to meet the nutrient requirements of livestock is the main limitation to the use of agro-industrial by- products (Chesworth *et al.*, 1989). Nkhonjera (1989) conducted a study in Malawi and observed that efficient utilization of agricultural by- products are hindered by their poor quality, insufficient resources such as purchasing power, and unskilled labour. According to Fomunyam (1985), there is variability in nutrient content of crop residues due to unsynchronized planting and harvesting. The physical nature of cereal crop residues often affect intake negatively resulting in slow growth of livestock. Hadjigeorgiou *et al.* (2003) showed that sheep and goat offered chopped crop residue forage increased their dry matter intake, and digestive efficiency with the reduction in particles size. Gertenbach (2005) observed that the presence of deleterious substances or anti-nutritional factor is a major criterion to use in considering any crop or residue as feed to animal. While some of these toxins are within tolerable limits resulting in poor performance of the animal, some in extreme proportion could result in death of animal. Moreover, there are other health concerns that could result from consuming these deleterious substances such as bloat, prussic acid poisoning, trace mineral deficiencies like iodine and choking.

2.10: Mineral elements in crop residues and sheep nutrition

McDowell *et al*. (1985) stated that mineral requirement of an animal essentially depends on the nature and level of production, age, level and chemical form of the element in the feed ingredients, interrelationships with other nutrients, supplemental mineral intake, breed and the animal adaption. Furthermore, for the mineral requirement of grazing animal to be met, adequate forage is essential, therefore any factor that greatly reduce forage intake, such as low protein (< 7%) content, increased lignifications will likewise reduce the total minerals consumed. Harris *et al.* (1994) observed that proper mineral nutrition and supplementation is essential to animal health and high levels of milk production. A lack of attention to the mineral content of the total ration frequently leads to increased disease and reproductive problems. Likewise, too great an emphasis on mineral supplements frequently leads to using a variety of costly supplements with no apparent justification.

Kabaija and Little (1989) observed that cattle diet based on crop residues are most likely not able to supply adequate Na, and are marginal to deficient in P and possibly Zn. These deficiencies could be eradicated except for Na by inclusion of adequate quantities of by-products in the ration. However, there is possibility that these minerals might not be completely available to animals due to their association with the indigestible fibre components of the residues. Tiruneh (2006) verified high urinary calcium concentrations as culprits in predisposing cattle and sheep to Urolithiasis (Urinary calculi). The mean urinary calcium concentrations of the clinical cases and apparently healthy cattle were 8.6 mg/l and 8.44mg/l respectively. Serum calcium concentrations in clinically ill rams were not significantly different from apparently healthy rams.

2.11: Nutrient requirements of sheep

Nutrient requirements of sheep vary with differences in age, body weight, and stage of production. The five major categories of nutrients required by sheep are: 1) water; 2) energy; 3) protein; 4) vitamins; and 5) minerals. During the grazing season, sheep are able to meet their Nutrient requirements from pasture, salt and mineral supplement. Hay is provided to the flock when forages are limited, and grain may be added to the diet at certain stages of production when additional nutrient supplementation is required. Small grain pastures or stockpiled fescue can supply up to one-half of the feed requirements of the ewe flock during the winter (Umberger, 1996).

Table 2.3: Energy requirements of sheep (expressed on 100% dry matter basis)

Body wt(Kg)	Wt change/day (g)	TDN (%)	DE (Mcal/kg)	ME (Mcal/kg)	Conc. (%)	Forage (%)	CP (%)	Ca (%)	P (%)
REPLACEMENT EWES LAMBS									
30	227	65	2.9	2.4	35	65	12.8	0.53	0.22
40	182	65	2.9	2.4	35	65	10.2	0.42	0.18
REPLACEMENT RAM LAMBS									
40	330	63	2.8	2.3	30	70	13.5	0.43	0.21
60	320	63	2.8	2.3	30	70	11.0	0.35	0.18

Source: Adapted from NRC nutrient requirement Table (1985).

Table 2.4: Minerals required by sheep

	Class of sheep and their mineral requirements (in diet dry matter)		
	Mature sheep		Young lambs
Nutrient	Early pregnancy	Nursing twins	Fast gain
Calcium (%)	0.25	0.4	0.55
Phosphorus (%)	0.2	0.3	0.25
Potassium (%)	0.5	0.8	0.6
Magnesium (%)	0.12	0.18	0.12
Sulphur (%)	0.15	0.25	0.15
Sodium (%)	0.10	0.15	0.10
Iron (PPM)	40	40	40
Copper (PPM)	10	10	10
Manganese (PPM)	40	40	40
Zinc (PPM)	30	30	30
Selenium (PPM)	0.3	0.3	0.3

Source: Adapted from Wahlberg and Greiner (2006).

For the last 20 years in Australia, the energy requirements of ruminant animals and the energy value of feeds have been expressed using a system based on metabolizable energy (ME). The system now favoured for describing protein nutrition was introduced in 1992. This system is based on metabolizable protein (MP) (Umberger, 1996).

2.12: Sheep growth and feed supplementation

Adu *et al.* (1992) fed sorghum Stover with urea and graded level of lablab purpureus to Yankasa sheep in Nigeria, Results from their study showed a depressed intake of sorghum Stover when supplemented with lablab but the overall intake improved with increasing levels of lablab supplementation. In addition, the inclusion of urea increased the Stover intake and the digestibility of the dry matter, neutral detergent fibre and nitrogen. These led to improved weight gains of the Sheep and therefore concluded in favour urea and lablab supplementation of sorghum Stover. Abate and Melaku (2009) conducted a study to assess the supplementation of Vetch and Lucerne hays on dry matter intake, digestibility and body weight gain of Arsi-Bale sheep. Their results showed that supplementation increased daily feed intake, as well as apparent digestibility. In conclusion, their results indicated that treating barley straw with urea and supplementation of Lucerne or vetch hay could serve as a useful strategy in improving smallholder sheep production in the tropics.

Chaturvedi *et al.* (2009) reported that average body weight gain and average daily gain of animal's stall fed (SF) was higher than animals on grazing and supplemented (GR). Stall fed animals received ad lib complete feed while the other group in addition to 8-hour per day grazing received supplemented concentrate pellets at 300g/head/day. They therefore concluded and recommended that stall feeding can be explored as an alternative to grazing and supplementation feeding strategy for sheep product.

2.13: Energy nutrition in sheep

The amount of energy in feed potentially utilizable by animals can be expressed in the form of gross energy (GE), digestible energy (DE), metabolizable energy (ME) or net energy (NE) for maintenance and production (ARC, 1980). Energy is the most common nutritional deficiency for ewes. Forages provide the primary, and in some cases, the sole source of energy. At production stages when energy requirements are increased (flushing, late gestation, lactation), energy can be supplemented with concentrate feeds such as barley, wheat, oats, and corn. An energy deficiency can reduce conception rate, reduce lambing rate and milk production. It may also negatively affect wool production. Energy deficiency is linked to greater susceptibility to parasite infestation and is also the primary cause of pregnancy toxaemia (ketosis) in late pregnancy.

Energy deficiency reduces rate of gain in growing animals. In severe cases, it causes weight loss or even death. Excess energy intake also can reduce productivity. Over-conditioned (fat) ewes are reproductively less efficient and have more lambing difficulties. Excess energy intake is most likely to occur in ewes grazing highly productive pastures after weaning their lamb (Johnson, 1997). Therefore, there is need for energy balance which is achieved when input (or dietary energy intake) is equal to output (or energy expenditure), plus the energy cost of growth in childhood and pregnancy, or the energy cost to produce milk during lactation.

A study by Hossain *et al* (2003) on the effects of dietary energy supplementation to grazing on feed intake, growth and reproductive performance of female goats showed that dry matter and crude protein intake decreased with increased level of energy supplementation. In addition, they mentioned that average daily weight gains as well as the birth weight increased with increasing level of energy supplementation. However, a study conducted with Kivircik ewes under a semi- intensive system showed that reproductive performance could be impaired by short-term increase in the level of dietary energy (Koyuncu and Conbolat, 2009).

According to Ocak *et al*., (2016), average daily feed intake, average daily gain and feed conversion efficiency, as well as dressing percentage of lamb was influenced by the level of dietary energy. Lambs fed low energy diet had a significant ($P<0.05$) increased feed intake than those fed medium and high energy diets. High energy diet fed to lambs resulted in a significant ($P<0.05$) increase in average daily gain than those fed medium and low energy diets. Feed conversion was deteriorated in lamb group fed low energy diet. Dressing percentage and body fat was highest in lamb fed high energy diet.

2.14: Protein nutrition in sheep

According to Hristov *et al.* (2004), excessive or high dietary protein (RDP) in ruminant diet is not efficiently utilized by rumen microbes and hence the animal. The result of their study showed that excess RDP in the diet of lactating dairy cows could not be used efficiently for microbial protein synthesis and was largely lost through urinary N excretion. At the similar metabolizable protein supply, increased crude protein or RDP concentration in the diet would result in decreased efficiency of conversion of dietary N into milk protein and less efficient use of ruminal ammonia N for milk protein synthesis.

According to McDonald (2002), the use of DCP (digestible crude protein) for evaluating food protein for ruminant has been abandoned due to critical role played by the rumen microbes in the provision of major energy requirement of the host animals in form of VFA (acetate, propionate and butyrate). Part of this energy produced is used up for growth and synthesis of microbial protein when nitrogen, peptides amino acids are available. Bacteria acting on the structural carbohydrate fraction of the diet use only ammonia, whereas those acting on non-structural faction (NSC) derive about 65 % of their nitrogen from amino acids and peptides, and the remainder from ammonia. The degree of contribution of microbial protein to the host animal is directly related to the speed and extent of microbial breakdown of the dietary nitrogen faction, the efficiency of the conversion of the degraded material into microbial protein, the digestibility of the microbial protein and the biological value of the latter.

Firkins (1996) reported that increasing starch in the diet decreases ruminal pH, which often decreases extent of ruminal fibre digestion and also may decrease efficiency of microbial protein synthesis because of energy- spilling reactions. Microbial protein supply to the duodenum should be maximized for efficient use of feed protein and energy. High producing ruminants often are fed significant concentrations of cereal grains and fat in their diets. In contrast, higher grain feeding increased efficiency of microbial protein synthesis in some studies because ruminal passage rate was increased. Ruminal degradation of carbohydrates and protein must be synchronized for optimal microbial efficiency, but the microbes appear to withstand transient periods of asynchronous nutrient supply in many cases. Protozoa extensively prey upon bacteria, and a higher proportion of protozoa than bacteria are found within the rumen, recycling significant amounts of protein. Feeding moderate amounts of unsaturated fat appears to reduce, especially on relatively low forage diets, protozoan numbers and the extent of intra ruminal recycling.

The efficiency of the rumen fermentation in yielding microbial protein is driven by two major factors; the rate of fermentation (amount of feed per unit time), and the rate of passage. The interaction between passage time and diet quality can make microbial efficiency highly variable. The microbial requirement for nitrogen may exceed that of protein requirement of the animal host. Microbial species requirement must also be considered, for example, cellulolytic organisms depend more on ammonia and iso-acids while amylolytic organisms prefers non-structural carbohydrates (Van Soest, 1994)

Daily microbial protein synthesis is different from efficiency of microbial protein synthesis. Daily microbial protein synthesis is a product of the efficiency of microbial protein synthesis which usually is defined as grams of microbial crude protein (MCP) per kilogram or 100 grams of organic matter (OM) digested in the rumen (Karsli and Russell, 2001). Efficiency of microbial protein synthesis greatly differs in animals fed different diets, even within similar diets. The average efficiency of microbial protein synthesis ranges from 7.5g to 24.3g for forage-based diets, ranging from 9.1g to 27.9g for forage- concentrate mix diets; range from 7.0g to 23.7 g MCP/100 g for concentrate (Karsil and Russell, 2001).

2.15: Fibre digestion

According to Kawas and Mahgoub (2005) dietary fibre contributes significantly to the balancing of nutrient requirements of goats. It influences the interaction between intake and digestion of nutrients. Dietary fibre intake influences mastication and rumen fermentation. Adequate dietary fibre is essential in producing leaner carcasses in growing goats and prevention of milk fat depression in lactation dairy goats. The effect is mediated through the maintenance of favourable acetate to propionate ratio in the rumen liquor, as acetate is the major precursor of milk fat. About 18-20% ADF or 41% NDF is nutritionally adequate for high producing lactating dairy goats (Christopher *et al.*, 2005).

Varga and Kolver (1997) observed that ruminal microbial populations attack, degrade and ferment structural carbohydrates in forage cell walls to provide VFA' S and protein to host animal. However, the rate and extent of fibre degradation is determined to a large extent by factors such as: microbial accessibility to substrates, physical and chemical nature of the forage and the kinetics of ruminal digestion. The physical and chemical nature of forages can present a barrier to the complex digestion in the rumen due to the association of lignin with polysaccharide constituents. Adhesion proteins allow bacteria to come in contact with their substrates. Fungi also play an important synergistic role in the ruminal digestion of forages by physically disrupting the lignified stem tissue with greater access to the plant stem and the digestible portions of the plant.

Dugmore (1995) stated that the presence of fibre in diets of ruminant animals has a number of advantages which include provision of a more continuous flow of fermentable carbohydrate to the ruminal micro-organisms thus ensuring overall utilization of the diet. In addition, butter fat production is maintained because acetic acid (which is the main fermentation product of long fibre) is an intermediate metabolite for milk fat. The roughage component of the diet should not be less than 35- 40% of the total dry-matter. Roughages should not be milled shorter than 10 mm in length in order to maintain its roughage character. Milling roughages too fine have been shown to reduce chewing activity. Proper balance of fibre: starch ratio will increase dry-matter intake and milk production (Dugmore, 1995).

Kawashima (2000) reported from a metabolism trial study conducted in Thailand using Sheep, Brahman cattle, Swamp buffalo and native Thai cattle fed Ruzi grass hay with different levels of soya bean meal that fibre digestibility was improved by the supplementation of Soya bean until the dietary crude protein content reached 10%. Beyond this level, the positive effect of supplements was not observed. In Brahman cattle, the fibre digestibility without protein supplement was lower than that with supplements (CP 6.5%). But no improvement by additional protein supplements at a level above (C.P 6.5%). Conversely, Buffalo and Thai native cattle fibre digestibility without supplements was not different from that with supplements.

CHAPTER THREE

3.0: EFFECT OF ENERGY INTAKE ON PERFORMANCE OF TSWANA SHEEP FED SORGHUM OR MILLET STOVER AS BASAL DIET

3.1: Abstract

There is an abundance of crop residues from sorghum, millet and maize in Botswana at harvest time. However, research suggests that very small amount of this cereal stover is utilized as animal feed. With that regard, the aim of this study was to determine the effect of dietary energy\ intake on performance of Tswana sheep when fed Sorghum or Millet Stover as basal diet with a concentrate mixture of sorghum bran, sunflower seed meal and mineral premixes as supplement at different energy levels. Tswana sheep were used in a 3 x 2 factorial arrangement in a Complete Randomized Design. The experimental diets fed were: T1= 40% Cenchrus hay + 30% sorghum bran + 28% sunflower meal + 2% mineral premix *(control), T2= 40% sorghum stover + 30% sorghum bran* + 28% sunflower meal + 2% mineral premix, *T3 = 50% sorghum stover + 20% sorghum bran* + 28% sunflower meal + 2% mineral premix, *T4= 40% millet stover + 30% sorghum bran* + 28% sunflower meal + 2% mineral premix, *T5= 50% millet stover + 20% sorghum bran* + 28% sunflower meal + 2% mineral premix. *Data collected were analysed statistically using the procedure General Linear Model in Statistical Analysis System (SAS) (SAS, 2004). The result indicated no differences in all the treatments for feed intake (FI), weight gain (WG), final weight (FW), average daily gain (ADG) and feed conversion ratio (FCR). It was concluded that millet and sorghum stover could substitute sorghum bran without any effect on performance characteristic of Tswana sheep.*

Key words: Energy intake, Millet, Performance, Sorghum, Tswana sheep

3.2: Introduction

In Botswana provision of adequate feed to livestock is generally a challenge to smallholder farmers. The problem is aggravated during dry periods when rangeland which primarily provides the bulk of feed is almost depleted of its nutritive plant resources (Aganga and Nsinamwa, 2007). This situation culminates in animals losing weight, body conditions and reproductive inefficiency. Most smallholders' farmers also engage in crop production especially cereals such as maize, sorghum and millet. These generate food and income to the famer, as well as residues which can be utilized as feed for the livestock. Maize, sorghum and millet stover are generated after harvest but the practice of allowing animals in to the field is wasteful as much of these residues are been trampled on (Tsopito, 2010). Nutritionally, these residues alone cannot meet the nutrient requirements of the animals and therefore need to the supplemented with concentrates, of which most smallholder farmers cannot easily afford. Other energy feeds such as Agro-industrial by-products such as Sorghum bran, Maize bran, Wheat bran and Brewer bran which can augment the energy level of feeds are somewhat judged expensive (Tsopito, 2010).

The energy availability from the feedstuffs and the energy requirement of animals are characterized by the metabolizable energy. The metabolizable energy of the feed (feedstuff, ration) is interpreted as potential energy. The metabolizable energy of a ration is estimated in consideration of energy level, live weight and protein production (protein in body gain and milk). Metabolizable energy can be approximated by multiplying digestible energy by a factor of 0.82 (ARC, 1980). Energy is the most common nutritional deficiency of small stock, especially ewes and it's therefore important that adequate provision be made through feed. Crop residues are generally low in energy since they contain a high proportion of indigestible fibrous matter. Energy content of stover ranges between 5.5 - 9.6 MJ/Kg DM. Energy values vary with the cereal or legume variety and the management of the residue after grain harvest. Stover is also low in crude protein and minerals (especially Phosphorus). In addition, the physical coarse form of most crop residues limits the activity of rumen microbes resulting in low passage rate through the digestive system, and hence low voluntary intake.

Supplementation of crop residues (with concentrate, molasses or mineral) is important to improve the nutritive value of these feeds. Supplementation provides essential nutrients and enhances the activities of rumen microbes with resultant better utilization of crop residues. Supplementation also improve voluntary feed intake. Agro - industrial by- products are generated as a result of processing food crops (like maize, sorghum, millet) and animal products (Bone, Blood, Carcass, Chicken litter). In Botswana, huge amount of these is not been utilized because most smallholder farmers lack the techniques of integrating them in their feeding systems.

3.2.1: Specific Objective

The specific objective of this research was to:

1. Determine the effect of dietary energy and metabolizable energy intake on Tswana sheep performance when fed Sorghum or Millet Stover as basal diet with a concentrate mixture of sorghum bran, sunflower seed meal and mineral premix as supplement at different energy levels.

3.2.2: Hypothesis

- **H_o:** Dietary energy intake does not affect feed intake, average daily gain, and feed conversion ratio of Tswana Sheep fed Sorghum Stover or Millet Stover.
- **H_a:** Dietary energy intake does affect feed intake, average daily gain, and feed conversion ratio of Tswana Sheep fed Sorghum Stover or Millet stover.

3.3: Materials and Methods

3.3.1: Study location

The study was carried out at the small-stock research unit of the Botswana University of Agriculture and Natural Resources, Sebele, which is located 10 km from Gaborone in South-East district of Botswana. The site is situated at 25.94^o S, 24.58^o E at an altitude of 991 meters, with mean annual rainfall of 350 millimetres and average monthly maximum temperatures of 34.4^{o}C and minimum of 15^{o}C (Animal Production Range and Research Division, 2011).

3.3.2: Feed preparation and analysis

Sorghum and Millet stover were bought from local farmers in Mosetse in the northern part of Botswana and transported to the research site in Sebele. They were stored in air-ventilated feed-shed until they were chaffed with a hammer mill [Model Drostsky hammer mill by Aktief (Pty) Ltd, South Africa] and stored in open bags. The size of the hammer mill sieve used was 1.5 cm because it was the only used for Smallstock feeds in the college. Sorghum bran was bought from the local brewers in Gaborone and sunflower meal was bought from local farmers in Mahalapye.

Five experimental diets were formulated based on the calculated nutrient contents (not analysed) of feed ingredients on dry matter basis to feed the sheep: T1= 40% Cenchrus hay + 30% sorghum bran + 28% sunflower meal + 2% mineral premix (control), T2= 40% sorghum stover + 30% sorghum bran + 28% sunflower meal + 2% mineral premix, T3 = 50% sorghum stover + 20% sorghum bran + 28% sunflower meal + 2% mineral premix, T4= 40% millet stover + 30% sorghum bran + 28% sunflower meal + 2% mineral premix, T5= 50% millet stover + 20% sorghum bran + 28% sunflower meal + 2% mineral premix (Table 3.1). T1 was included as the control to compare the efficiency of using cenchrus hay to that of stover in terms of animal performance and their affordability.

Table3.1: Proportions of feed ingredients in experimental treatments

Ingredients (%)	Types of treatment				
	T1	T2	T3	T4	T5
Cenchrus hay	40	-	-	-	
Sorghum stover	-	40	50	-	-
Millet stover	-	-	-	40	50
Sorghum bran	30	30	20	30	20
Sunflower meal	28	28	28	28	28
Dical. PO_4	1.0	1.0	1.0	1.0	1.0
Iodized salt	0.5	0.5	0.5	0.5	0.5
Mineral Premix.	0.5	0.5	0.5	0.5	0.5
Calculated nutrient contents of the rations on dry matter basis					
Crude Protein %	12.21	12.12	12.11	12.08	12.31
T D N %	65.10	64.60	64.53	69.94	68.21
Calcium %	0.63	0.61	0.64	0.38	0.35
Phosphorus %	0.37	0.41	0.39	0.27	0.22
ME Kj/g	2280	2270	2260	2250	2290

T1= Cenchrus hay (40%) + supplements (60%) Control, T2= Sorghum Stover (40%) + supplements (60%), T3=Sorghum Stover (50%) + supplements (50%), T4= Millet Stover (40%) + supplements (60%), T5= Millet Stover (50%) + supplements (50%), Dcal. $PO_{4=}$ dicalcium phosphate, TDNA%= total digestible nutrients, ME= energy for maintenance (Kilojoules per gram).

3.3.3: Animals, diets and management

Twenty-five Tswana castrates sheep sourced from the Botswana University of Agriculture and Natural Resources farm (6 months of age and average weight of 22.5kg) were used for the experiment. The sheep were intensively managed and housed individually in pens of 9.6 m^2 which had concrete floors and corrugated iron roofs. The sheep were vaccinated against Pulpy Kidney and Pasteurella diseases (Pulpy Kidney and Smallstock Pasteurella vaccines, Onderstepoort Biological Products Company, South Africa), dewormed against internal parasites (Ecomectin®, Intervet, South Africa) and dipped for external parasites (Drastic DeadlineTM, Bayer® Animal Health, South Africa) before the start of the experiment. Five sheep were randomly allocated to each of the five treatment diets. The experimental diets fed were: T1= 40% Cenchrus hay + 30% sorghum bran + 28% sunflower meal + 2% premixes (control), T2= 40% sorghum stover + 30% sorghum bran+ 28% sunflower meal + 2%

premixes, T3 = 50% sorghum stover + 20% sorghum bran + 28% sunflower meal + 2% premixes, T4= 40% millet stover + 30% sorghum bran + 28% sunflower meal + 2% premixes, T5= 50% millet stover + 20% sorghum bran + 28% sunflower meal + 2% premixes.

There was a two-week adaptation period on a daily diet of *Cenchrus ciliaris* hay fed *ad libitum* and 250g of sorghum bran per sheep, which was followed by ten weeks (70 days) experimental period. Each sheep was given a treatment diet at 4% body weight per day. Fresh feed offered to the sheep was weighed and recorded every morning using CFW-32 electronic platform scale (± 5g, Adam Equipment 2006-Software version V1.04). The feed was offered in the morning at 08:00 hours. Removal of orts was done every morning before placement of fresh feed. The orts were collected and weighed to determine the actual daily feed intake. The sheep were weighed every two (2) weeks in the morning before they were given the feed and water to measure their weights and determine their gains or loss. Body weight of the sheep was measured using Salter Suspended weigher (200kg±500g - manufactured by Tal-Tec). Clean drinking water was provided *ad libutum* for the sheep.

3.4: Data collection

The performance parameters measured were feed intake (FI) = Quantity of feed offered – left over feed; weight gain (WG) = Final weight – Initial weight; Average daily gain (ADG) and feed conversion ratio (FCR). Average daily gain (ADG) and feed conversion efficiency (FCR) was calculated by using the formulae:

ADG = Final weight (kg) - Initial weight (kg) ÷ Number of days of the experimental period.

FCR = Feed intake (kg) ÷ Weight gain (kg) during the experimental period.

3.5: Experimental design and statistical analysis

The experimental design was a 3 x 2 factorial arrangement in a Complete Randomized Design with five replications per each treatment. Cenchrus hay, Sorghum and millet stover were the main factors. Data collected were analysed statistically using the procedure General Linear Model in Statistical Analysis System (SAS) (SAS, 2004). Least significant difference test was used for mean separation using SAS (2004) package. The difference between the means was significant when it was greater than the statistical Least Significant Difference (LSD) value.

Experimental model:

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + €_{ijk}$

Where;

Y_{ijk} = response variable (feed intake or weight gain of sheep fed stover at different energy levels)

μ = overall mean,

αi = i^{th} (1,2,3) the effect of basal diets = (Cenchrus, sorghum, millet)

βj = j^{th} (1,2) the effect of energy levels = (40%, 50%)

$(\alpha\beta)_{ij=}$ interaction between sorghum and millet stover

$€_{ijk}$ = random variation N~ (0, α/2)

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3.5: Results and Discussions

Table 3.2: Effects of treatment interactions on feed intake and body weight gain of Tswana sheep

Least square means for effect Treatment					
Parameters	T2 x T4	T3 x T5	T2 x T3	T4 x T5	Pr > |t|
Feed Intake (kg)	0.53	0.45	0.26	0.82	< 0.0001
Weight Gain (kg)	0.65	0.46	0.87	0.31	< 0.0001
Initial Weight (kg)	0.94	0.77	0.82	1.00	< 0.0001
Final Weight (kg)	0.96	0.64	0.80	0.78	< 0.0001
Average Daily Gain (kg)	0.55	0.47	0.77	0.30	< 0.0001
Feed Conversion Ratio	0.60	0.93	0.79	0.38	< 0.0001

T2 x T4 = interaction of 40% sorghum stover x 40% millet stover, T3 x T5= interaction of 50% sorghum stover x 50% millet stover, T2 x T3= interaction of 40% sorghum stover x 50% sorghum stover, T4 x T5= interaction of 40% millet stover x 50% millet stover.

There was no significant difference between interaction of millet and sorghum stover on feed intake, average daily gain and feed conversion ratio (Table 3.2).

Table 3.3: Effects of energy level in total mixed ration on feed intake and body weight gain of Tswana sheep

Parameters	**Experimental treatments (LSM)**					
	T1	T2	T3	T4	T5	LSD
Feed Intake (g)	843.30	698.80	785.50	715.70	759.60	228.56
Weight Gain (Kg)	7.23	6.42	6.60	5.80	6.92	2.22
Initial Weight(kg)	22.92	22.80	23.60	22.52	22.52	7.21
Final Weight (kg)	30.20	28.32	29.44	29.22	30.15	8.11
Average Daily Gain (g)	103.40	83.00	94.00	89.60	98.80	31.23
Feed Conversion Ratio	1.16	1.08	1.19	1.23	1.09	1.02

T1= 40% Cenchrus hay + 30% sorghum bran (control), T2= 40% sorghum stover + 30% sorghum bran, T3 = 50% sorghum stover + 20% sorghum bran, T4= 40% millet stover + 30% sorghum bran, T5= 50% millet stover + 20% sorghum bran. LSD= least significant difference.

Table 3.3 shows the result of the performance characteristics of sheep fed forage diets. The result showed that there was no significant difference (the difference between the means was less than the statistical Least Significant Difference) in all the parameters measured; feed intake, weight gain, average daily gain and the feed conversion ratio. Feed intake ranged from 698.8 g (T2) to 843.3 g (T1), and average daily gain between 83.0 g (T2) to 103.4 g (T1). Our findings agree with that of Mohammed *et al*., (1989) when evaluated the effects of incorporating processed sorghum stover in total mixed rations for finishing cattle. Their results showed that treatments had no significant effect on dry matter intake and rate of body weight gain. Mohammed *et al*., (2016) determined the effect of treatments on dry matter intake of millet straw by rams and found no significant difference between treatments. Singh *et al*., (2017) conducted in vivo studies to assess the nutritive value of diets containing different sorghum stover varieties fed to sheep. Their results showed no differences in intake and digestibility of dry matter of the stover varieties. In contrary, Blummel and Reddy (2006) observed significant differences in organic matter digestibility, and intake of the various sorghum stover treatments when fed to growing male sheep. A study by Abdou *et al*., (2011) when supplementing millet stover with groundnut haulms and wheat bran showed an increase in body weight gain and feed conversion efficiency in lambs. Legodimo *et al*., (2016) highlighted that dry matter intake of forage-based diets are related to the level of physically effective neutral detergent fibre it contains. Moreover, Abdou (2010) highlighted that the nutritive value of feed influences its digestibility and therefore its intake.

This study produced feed conversion ratio that ranged from 1.08 kg (T2) to 1.23 kg (T4). The feed conversion ratio of the sheep was influenced by the level of digestibility of the total mixed rations. On average rations with high total digestible nutrients had high feed conversion ratio and vice versa. Even though there were no significant differences in the measured parameters, sheep which were fed T4 ration had high mean values than the rest of the treatment groups. Our results were in line with that of Aganga and Autlwetse (2000) who conducted a feeding trial to investigate the performance of sheep fed *Lablab purpureus* + *Cenchrus ciliaris* (control), L. purpureus + sorghum forage, L. purpureus +millet forage and L. purpureus + veldt grass. They reported insignificant differences in the feed conversion efficiency of all the treatments. In contrary, they reported significantly higher DM intake in the diet containing Cenchrus hay than the group with sorghum and millet forage. They attributed the higher intake to the differences in the texture of the grasses which might have influenced the voluntary intake of the animal. Grinding usually avails a larger surface area for microbial action by breaking the lignin bonds of forage and exposing cellulose and hemicelluloses for microbial degradation (Mohammed *et al*., 2016). Aganga and Autlwetse (2000) reported significant differences in the average body weight gain of the sheep. They concluded that millet or sorghum stover could substitute portions of sorghum bran without any effect on performance characteristic. Van Soest (1994) pointed out that high feed intake promotes both escape protein and increase microbial protein synthesis in the rumen. Moreover, microbial protein synthesis in the rumen accounts for 50 to 80 % of total absorbable protein (Stern *et al*., 2006). However, in a study conducted by Babu *et al.*, (2014) when evaluating the nutrient digestibility of sweet sorghum stover and unconventional roughage in ram lambs in comparison to conventional sorghum and maize stover found no significant difference in nutrient digestibility of the ration fed to ram lambs.

3.6: Conclusion

Feeding Tswana sheep with sorghum and millet stover as basal diet with a concentrate mixture of sorghum bran, sunflower seed meal and molasses as supplement at different energy levels improved feed intake, feed conversion ratio and weight gains. Daily feed intake was high on sheep that were fed Cenchrus hay, Sorghum stover and Millet stover respectively. Moreover, the more total digestible nutrients the ration had (e.g. Cenchrus hay), the more the metabolizable energy hence higher feed intake and more weight gain. On average rations with high total digestible nutrients had high feed conversion ratio and vice versa. Even though there were no differences in the measured parameters millet and sorghum stover when supplemented with sunflower seed meal could substitute portions of sorghum bran without any effect on average daily feed intake, average feed conversion ratio and average daily weight gain of Tswana sheep.

CHAPTER FOUR

4.0: EFFECT OF MINERALS ON PERFORMANCE, CARCASS CHARACTERISTICS, BLOOD AND LIVER MINERAL CONCENTRATION OF TSWANA SHEEP

4.1: Abstract

The objective of this study was to determine the effect of minerals on performance, carcass characteristics and blood and liver mineral concentration of Tswana sheep when fed Sorghum Stover or Millet Stover as basal diet supplemented with Sorghum bran, Sunflower seed meal, Dicalcium phosphate, salt and vitamins premix. The experimental diets were T1= Cenchrus hay (50%) + supplements with minerals (50%) , T2 = Cenchrus hay (50%) + supplements without minerals (50%) , T3 = Sorghum Stover (50%) + supplements with minerals (50%) , T4= Sorghum Stover (50%) + supplements without minerals (50%) , T5 = Millet Stover (50%) + supplements with minerals (50%) , T6 = Millet Stover (50%) + supplements without minerals (50%) minus minerals, The result indicated no significant effects on Feed Intake, Weight Gain, Final Weight, Average Daily Gain, Feed Conversion Ratio , carcass weight, chuck blade weight, flank weight, leg weight, neck weight, breast weight and femur length. The data showed that T1, T3 and T5 differed significantly from T2, T4 and T6 in blood and liver Ca, P, Mg and Na concentrations. The result also showed that T1, T3 and T5 differed significantly from T2, T4 and T6 in blood and liver Cu, Fe, Zn and Mn concentrations. It was concluded that minerals supplementation should be included in Tswana sheep diet in order to avert minerals deficiencies since their deficiencies affect livestock performance.

Key words: Carcass characteristics, mineral concentration, performance, Tswana sheep

4.2: Introduction

Indigenous Tswana sheep are important domestic animals in Botswana. They contribute immensely to the economy and food security of many smallholder farmers (Mrema and Rannobe, 2000). However, their productivity is constrained by shortage of good-quality feed, especially during the long dry season (Brown *et al*., 2016). There is insufficient plant biomass to support the production of sheep in this period, resulting in poor reproductive performance and slow attainment of market weight. Alternative feed resources may alleviate this nutritional fluctuation. Crop residues when supplemented with mineral concentrates have high potential values as sources of feed for ruminant livestock during the austere period (Mapiye *et al*., 2011).

Trace mineralized salt and commercial trace mineral supplements often do not supply as much copper, cobalt, manganese, and zinc as recommended by the National Research Council (2007) (Hill *et al*., 2010). Additionally, previous researches have questioned whether trace minerals even need to be supplemented to diets for finishing sheep. However, supplementation with these trace minerals is based largely on measurements other than performance (Hill *et al*., 2010). Most of the studies in the literature have compared inorganic with organic forms of minerals at a specific level of supplementation and have not tested whether either is needed or beneficial (Hill *et al*., 2010).

The importance of studies about the carcass components is associated not only with the possibility of increasing the economic return of the commercialization of sheep products, but also with the feed and raw materials which are lost and that could collaborate with the improvement of the nutritional level of human populations (Lima *et al*., 2013). The manipulation of the diets, in addition to improving the quality of sheep products, increases profitability in the production of lambs, but an increase in the use of the animal as a whole is also necessary to make the activity profitable (Shapiro *et al*., 1996). In view of this, alternative sources of feed ingredients in sheep diets should be searched in order to improve production. This study was carried out to determine the effects of minerals on performance, carcass characteristics, blood and liver mineral concentration of Tswana sheep.

4.2.1: Specific objective

The objective of this study was to:

- Determine the effect of dietary mineral intake on feed intake, average daily gain, feed conversion ratio, carcass characteristics, blood and liver mineral concentration of Tswana sheep when fed Sorghum Stover or Millet Stover as basal diet supplemented with Sorghum bran, Sunflower seed meal, Dicalcium phosphate, salt and vitamins premix.

4.2.2: Hypothesis:

- Ho: Dietary mineral intake does not affect feed intake, average daily gain, feed conversion ratio, carcass characteristics, blood and liver mineral concentration of Tswana Sheep fed sorghum or Millet stover at different energy levels.

- Ha: Dietary mineral intake does affect feed intake, average daily gain, feed conversion ratio, carcass characteristics, blood and liver mineral concentration of Tswana Sheep fed sorghum or millet stover at different energy levels.

4.3: Materials and Methods

4.3.1: Study location

The study was carried out at the small-stock research unit of the Botswana University of Agriculture and Natural Resources, Sebele. Sebele is located 10 km from Gaborone in South-East district of Botswana. The site is situated at 25.94^{o} S, 24.58^{o} E at an altitude of 991 meters, with mean annual rainfall of 350 millimetres and average monthly maximum temperatures of 34.4^{o}C and minimum of 15^{o}C (Animal Production Range and Research Division, 2011).

4.3.2: Feed preparation and analysis

Sorghum and Millet stover were bought from local farmers in Mosetse in the northern part of Botswana and transported to the research site in Sebele. They were stored in air-ventilated feed-shed until they were chaffed with a hammer mill [Model Drostsky hammer mill by Aktief (Pty) Ltd, South Africa] and stored in open bags. The size of the hammer mill sieve used was 1.5 cm because it was the only used for Smallstock feeds in the college. Sorghum bran was bought from the local brewers in Gaborone and sunflower cake was bought from local farmers in Mahalapye.

Six experimental diets were formulated to feed the sheep: The experimental diets were T1= Cenchrus hay (50%) + supplements (50%) plus mineral, T2 = Cenchrus hay (50%) + supplements (50%) minus mineral, T3 = Sorghum Stover (50%) + supplements (50%) plus minerals, T4= Sorghum Stover (50%) + supplements (50%) minus minerals, T5 = Millet Stover (50%) + supplements (50%) + minerals, T6 = Millet Stover (500%) + supplements (50%) minus minerals. The mineral supplements used were dicalcium phosphate, iodized salt and Vitamin premix.

4.3.3: Animals, diets and management

Tswana sheep castrates sourced from the Botswana University of Agriculture and Natural Resources farm (8 months of age and average weight of 30 kg) was used for the experiment. The sheep were intensively managed and housed individually in pens of 9.6 m^2 which had concrete floors and corrugated iron roofs. The sheep were vaccinated against pulpy kidney and Pasteurella diseases (Pulpy Kidney and Smallstock Pasteurella vaccines, Onderstepoort Biological Products Company, South Africa), dewormed against internal parasites (Ecomectin®, Intervet, South Africa) and dipped for external parasites (Drastic DeadlineTM, Bayer® animal Health, South Africa) before the start of the experiment. Six sheep were randomly allocated to each of the six treatment diets. The experimental diets were T1= Cenchrus hay (50%) + supplements with minerals (50%), T2 = Cenchrus. hay (50%) + supplements without minerals (50%), T3 = Sorghum Stover (50%) + supplements with minerals (50%), T4= Sorghum Stover (50%) + supplements without minerals (50%), T5 = Millet Stover (50%) + supplements with minerals (50%), T6 = Millet Stover (50%) + supplements without minerals (50%). The mineral supplements used were dicalcium phosphate, iodized salt and Vitamin premix.

There was a two-week adaptation period on a daily diet of *Cenchrus cilliaris* hay fed *ad libitum* and 250g of sorghum bran per sheep, which was followed by twelve weeks (84 days) experimental period. Each sheep was given a treatment diet at 4% body weight per day. Fresh feed offered to the sheep was weighed and recorded every morning using CFW-32 electronic platform scale (± 5g, Adam Equipment 2006-Software version V1.04). The feed was offered in the morning at 08:00 hours. Removal of orts was done every morning before placement of fresh feed. The orts were collected and weighed to determine the actual daily feed intake. The sheep were weighed every two (2) weeks in the morning before they were given the feed and water to measure their weights and determine their gains or loss. Body weight of the sheep was measured using Salter Suspended weigher (200kg±500g - manufactured by Tal-Tec). Clean drinking water was provided *ad libutum* for the sheep.

Table 4.1: Experimental feed ingredients

Ingredients (%)	Types of treatment					
	T1	T2	T3	T4	T5	T6
Cenchrus hay	50	50	-	-	-	-
Sorghum stover		-	50	50	-	-
Millet stover		-	-	-	50	50
Sorghum bran	22.60	22.60	20.43	22.09	20.22	22.04
"Chibuku" spent grain	18.55	20.55	20.18	22.18	20.33	22.22
Sunflower cake	6.85	6.85	7.39	5.73	7.45	5.74
Dical PO_4	1.0	-	1.0	-	1.0	-
Iodized salt	0.5	-	0.5	-	0.5	-
Vitamin premix	0.5	-	0.5	-	0.5	-

Calculated analysis of experimental feed ingredients (not analysed)						
CP	12.26	12.42	12.12	12.27	12.53	12.62
T D N (%)	67.73	67.73	66.77	64.28	65.49	67.25
ME(Kcal/kg)	2.93	2.93	2.97	2.80	2.90	2.87

T1= Cenchrus hay (50%) + supplements (50%) plus mineral , T2 = Cenchrus .hay (50%) + supplements (50%) minus mineral , T3 = Sorghum Stover (50%) + supplements(50%) plus minerals, T4= Sorghum Stover (50%) + supplements (50%) minus minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, 6 = Millet Stover (500%) + supplements (50%) minus minerals, TDN = Total Digestible Nutrients, ME= Metabolizable Energy, Dical PO_4 = Dicalcium Phosphate

4.3.4: Data collection

Six Sheep were slaughtered at the beginning of the study for baseline data on minerals evaluation in the blood and liver. Blood samples were obtained from sheep in the beginning of the study and fortnightly until end of the study. Representative blood samples were obtained from the jugular vein and the plasma or serum were separated immediately, and then later analysed for minerals. The performance parameters measured were feed intake (FI) = Quantity of feed offered – left over feed; weight gain (WG) = Final weight – Initial weight; final weight (FW), Average daily gain (ADG) = WG/ Days of trial, and feed conversion ratio (FCR) = Quantity of feed taken during trial/ Weight gain during trial.

At the end of the trial all the 36 sheep were transported to Botswana Meat Inspection and Training Centre abattoir and processed according to the standard abattoir procedures. After dressing and evisceration procedures, carcasses were weighed to obtain hot carcass weights and cut up into 5 primal cuts (rib, chuck blade, flank, leg and neck), which were individually weighed using digital scale. The carcass characteristics measured were: hot carcass weight, chuck blade weight, flank weight, leg weight, neck weight, and breast weight and femur length. Liver samples (50-100g was cut from the right lobe) from slaughtered animals and analysed for minerals. The macro minerals determined were Calcium (Ca), Phosphorus (P), Magnesium (Mg) and Sodium (Na) while the micro minerals were Copper (Cu), Iron (Fe), Zinc (Zn) and Manganese (Mn). Flame photometer and atomic spectrophotometer were used in the determination of the minerals.

4.3.5: Experimental model and Statistical analysis

The data for feed intake and weight gains of sheep fed crop residues were analysed (SAS: Statistical Analysis System, SAS Institute Inc. 2004) using General Linear Model Procedure according to a 3 x 2 factorial arrangement with stover and mineral supplementation as the main effects in a Randomized Complete Design. In case of significant difference among treatment means, Least Significant Difference (LSD) test was used to separate the means.

Experimental model:

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + €_{ijk}$

Where;

Y_{ijk} = response variable (feed intake or weight gain of sheep fed stover at different mineral levels)

μ = overall mean,

$\alpha i = i^{th}$ (1,2,3) the effect of stover = (sorghum stover, millet stover, and Cenchrus hay)

$\beta j = j^{th}$ (1,2) the effect of mineral level (0%, 1.5%)

$(\alpha\beta)_{ij=}$ interaction between stover and mineral level

$€_{ijk}$ = random variation N~ (0, α/2)

4.4: Results and Discussion

There was no significant difference between interaction of forage type and mineral level on feed intake, average daily gain and feed conversion ratio.

Table 4. 2: Performance characteristics of sheep fed experimental diet

Parameters	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Feed Intake(g)	894.5	820.9	926.9	767.1	783.3	812.4	23.45
Weight Gain(kg)	8.92	7.26	7.03	5.48	6.3	4.48	0.509
Initial weight(kg)	22.68	22.88	23.12	22.72	23.00	22.96	0.592
Final Weight(kg)	31.60	30.14	30.15	28.20	29.30	27.44	0.713
Average Daily gain(kg)	0.106	0.086	0.084	0.065	0.075	0.053	3.84
Feed Conversion Ratio	8.44.	9.55	11.03	11.80	10.44	15.33	0.49

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral, T3 = Sorghum Stover (50%) + supplements (50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals, T5 = Millet Stover (50%) + supplements (50%) + minerals, 6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= Least square means, LSD= Least significant difference.

Table 4.2 shows the performance characteristics of sheep fed the experimental diet. The main treatments effects (Cenchrus hay, sorghum and millet stover with mineral supplements) were responsible for the numerical differences in final weight, weight gain, feed intake and average daily weight gains amongst Tswana sheep. However, there was no significant difference (the difference between the means was less than the statistical Least Significant Difference) between the treatment rations on all measured parameters in sheep. Total mixed ration (T3) that had Sorghum Stover (50%) + supplements with minerals (50%) produced high feed intake, final weight, and average daily gain in Tswana sheep than other treatment groups (Table 4.2). The treatment rations used in this study produced total feed intake that ranged from 767.1g (T4) to 926.9g (T3), and daily weight gain between 4.48kg (T6) to 8.92kg (T1). Despite the fact that there were no differences in the performance parameters, the feed conversion ratios and the average daily gains of the treatment groups with minerals were better. This result is consistent with the findings of Fazlallah and Shahab (2015) who did not find differences in the initial and final weights of grazing sheep supplemented with or without minerals. The authors also did not find any significant differences in daily weight gains of the treatment and control groups, however, the group with mineral supplement numerically gained higher. This result is also in agreement with the findings of Rajbari and Rasti (2001) and that of White (1992) who did not find any significant differences in daily weight gain of lambs in grassland and grazing sheep respectively. Dietary minerals are involved as essential parts of many physiological activities such as energy production, enzyme activity, and vitamin and tissue synthesis. Their deficiencies have negative impacts on the reproductive efficiency of farm animals (Ibrahim *et al*., 2013).

Table 4.3: Carcass characteristics of sheep fed experimental diet

Parameters	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Carcass weight (Kg)	16.78	15.84	16.22	15.36	15.12	13.94	0.452
Rib(kg)	0.82	0.78	0.75	0.76	0.78	0.68	0.038
Chuck blade(kg)	0.479	0.39	0.477	0.452	0.452	0.389	0.018
Flank(kg)	0.783	0.678	0.773	0.755	0.762	0.681	0.033
Leg(kg)	1.677	1.714	1.588	1.38	1.445	1.524	0.056
Neck(kg)	0.735	0.747	0.922	0.72	0.668	0.713	0.037
Breast(kg)	0.522	0.538	0.565	0.509	0.483	0.44	0.023
Femur(cm)	17.44	17.8	17.9	16.84	17.92	16.76	0.0327

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM=Least square means, LSD= Least significant difference.

Result of the carcass characteristics of experimental animals is shown in Table 4.3. The average carcass weight of the Tswana sheep was numerically influenced by the treatment rations. The sheep feeding on rations containing Cenchrus hay (50%) + supplements with minerals (50%) (T1) had high carcass weight of 16.78kg followed by sheep feeding on rations containing Sorghum Stover (50%) + supplements with minerals (50%), (T3) (16.22 kg) and T2 (15.84 kg). It was also noted that high chuck blade weight was found in sheep that had high carcass weight, and low carcass weight produced less chuck blade weight. The data showed that there were no significant differences in all the carcass parameters measured. This implied that both the control and the treatment groups had enough minerals in their feed even when not supplemented with extra minerals. This result is in agreement with the findings of Fazlallah and Shahab (2015) who did not find any significant differences in hot and cold carcass weights, carcass bone weights, and carcass offal weights. According to Elias *et al*., (2015), the law of harmony anatomical can be used to explain the results better because carcasses with similar weights and amounts of fat means that all body areas are in similar proportions. The chemical composition of body tissues generally reflects the dietary status of animals. Elias *et al*. (2015) stated that the nutritional management of the animal can affect meat quality and weight, carcass yield and retail cuts, which are extremely important for measuring the animal process of meat production.

Table 4.4: Blood and liver Calcium (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Ca content(mg/g)	184.97	184.97	184.97	185.03	184.90	184.93	33.44
Final Ca content(mg/g)	512.67[a]	305.00[b]	495.00[a]	302.33[b]	492[a]	300.00[b]	45.94
Absorbed Ca (mg/g)	327.70[a]	120.03[b]	310.03[a]	117.30[b]	307.10[a]	115.07[b]	55.34
Liver							
Initial Ca content(mg/g)	214.97	214.97	214.97	214.97	214.97	214.97	33.44
Final Ca content(mg/g)	552.67[a]	345.00[b]	535.00[a]	342.33[b]	532.00[a]	340.00[b]	45.94
Absorbed Ca (mg/g)	337.70[a]	130.03[b]	320.03[a]	127.30[b]	317.10[a]	125.07[b]	55.34

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM=Least square means, LSD= Least significant difference, Ca= calcium.

Table 4.4 shows the result of the blood and liver calcium utilization of experimental animal. The data showed significant differences (the difference between means was greater than the statistical Least Significant Difference) in the final blood Ca contents and absorbed Ca of treatment groups with and without mineral supplementation. Sheep on T1 had 327.7 mg/g Ca absorption and differed from those on T2 with 120.03 mg/g Ca absorption. Sheep on T3 had 310.03 mg/g Ca and differ significantly from those of T4 with 117.30 mg/g absorption. The result showed that sheep on T5 differed from those on T6 with Ca absorption of 307 and 115.07 mg/g respectively. However, sheep on T1, T3 and T5 were the same in Ca absorption while those on T2, T4 and T6 were also not different in calcium absorption. Result of the liver Ca absorption showed that sheep on T1 differed from those on T2 with mean values of 337.70 and 130.03 mg/g respectively while those on T3 and T4 also differed having mean values of 320.03

and 127.30 mg/g respectively. Sheep on T5 had 317.10 while those on T6 had 125.07 mg/g absorbed liver Ca and differ significantly. Sowande *et al* (2008) reported blood Ca content of grazing West African Dwarf sheep during the wet and dry season as 8.5±0.19 and 6.02±0.25 mmol/L respectively while Langerite *et al* (2012) reported mean values of 359.9 and 362.0 mg/g rib carcass Ca concentration for sheep grazing during the dry and wet season respectively. The high blood and liver Ca concentration of the treatment group with mineral supplement could be attributed to the inclusion of source of Ca in the feed in the form of dicalcium phosphate.

Table 4.5: Blood and liver Phosphorus (mg/g) utilization of experimental animals

mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial P content(mg/g)	179.07	179.07	179.07	179.07	179.07	179.07	1.44
Final P content(mg/g)	304.3^{b}	212.63^{c}	347.07^{a}	208.03^{c}	316.77^{b}	206.27^{c}	28.98
Absorbed P(mg/g)	125.23^{b}	33.57^{c}	168.00^{a}	28.97^{c}	137.70^{b}	27.20^{c}	14.50
Liver							
Initial P content(mg/g)	199.07	199.07	199.07	199.07	199.07	199.07	1.44
Final P content(mg/g)	324.30^{b}	232.63^{c}	367.07^{a}	228.03^{c}	336.77^{b}	226.27^{c}	28.98
Absorbed P(mg/g)	125.23^{b}	33.57^{c}	168.00^{a}	28.97^{c}	137.70^{b}	27.20^{c}	82.11

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference. P=Phosphorus.

Table 4.5 shows the result of the blood and liver Phosphorus utilization of experimental animals. The blood phosphorus absorbed by sheep fed on T1 was 125.23mg/g and differed significantly from those on T2 which had 33.57mg/g. Sheep fed on T3 absorbed 168.00mg/g phosphorus while those fed on T4 absorbed 28.97mg/g of phosphorus and were significantly different. The phosphorus absorbed by sheep fed on T5 was 137.70mg/g and significantly differed from those fed on T6 had 27.20 mg/g absorption. The result also showed that sheep fed on T1 absorbed 125.23 mg/g of phosphorus in the liver and differed significantly from those fed on T2 with phosphorus absorption rate of 33.57 mg/g. The liver phosphorus absorption for sheep fed on T3 and T4 were 168.00 and 28.97 mg/g respectively and differed significantly. Sheep fed on T5 absorbed 137.70 mg/g phosphorus and differed significantly from those fed on T6 with 27.20 mg/g absorption.

It was established from the data that the treatment group with mineral supplementation had both their blood and liver phosphorus level elevated and this could be attributed to the inclusion of phosphorus in the form of dicalcium phosphate and those supplied by the premix included in the diet. Sowande *et al* (2008) reported values of 3.24±01 and 3.68±0.08 mmol/L phosphorus blood concentration in West African Dwarf sheep grazing during the wet and dry season respectively while Lengarite *et al* (2012) reported values of 157.0 and 147.0 mg/g for sheep rib carcass phosphorus concentration during the dry and wet season in three grazing sites of Kenya.

Table 4.6: Blood and liver Magnesium (mg/g) utilization of experimental animals

mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Mg content(mg/g)	24.03	24.03	24.03	24.03	24.03	24.03	6.68
Final Mg content(mg/g)	65.43^{a}	41.90^{b}	63.63^{a}	34.20^{b}	62.70^{a}	37.67^{b}	8.30
Absorbed Mg (mg/g)	41.40^{a}	17.87^{b}	39.60^{a}	10.17^{b}	38.67^{a}	13.63^{b}	10.53
Liver							
Initial Mg content(mg/g)	34.03	34.03	34.03	34.03	34.03	34.03	6.68
Final Mg content(mg/g)	85.43^{a}	61.90^{b}	83.63^{a}	54.20^{b}	82.70^{a}	57.67^{b}	8.30
Absorbed Mg (mg/g)	51.40^{a}	27.87^{b}	49.60^{a}	20.17^{b}	48.67^{a}	23.63^{b}	10.53

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Mg= Magnesium.

The blood and liver magnesium utilization is shown in Table 4.6. The results of magnesium blood concentration showed that sheep on T1 and T2 absorbed 40.40 and 37.87mg/g of Mg respectively and differ significantly. Sheep on T3 and T4 absorbed 39.60 and 10.17mg/g Mg respectively and differed significantly while those on T5 and T6 absorbed 38.67 and 13.63 mg/g of Mg respectively and also differed significantly. The liver Mg concentration showed that sheep on T1 and T2 absorbed 51.40 and 27.87mg/g of Mg respectively and differed significantly while those on T3 and T4 absorbed 49.60 and 20.17mg/g of Mg respectively and also differed significantly. Sheep on T5 differed from those on T6 with Mg absorption of 46.67 and 23.63mg/g respectively.

The treatments groups with mineral supplementation had higher blood and liver concentration of Mg and this could be attributed to the addition of the mineral supplements in the form of premix. Sowande *et al.* (2008) reported blood Mg concentration of 0.70±0.02 and 0.76±0.03 mmol/L for WAD sheep grazing in wet and dry season respectively while Lengarite *et al.* (2012) reported values of 9.56 and 8.54 mg/g respectively for sheep rib carcass Mg concentration during the dry and wet season in three grazing sites of Kenya.

Table 4.7: Blood and liver Sodium (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM) T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Na content(mg/g)	61.13	61.13	61.13	61.13	61.13	61.13	15.69
Final Na content(mg/g)	124.67 ^{a}	91.40 ^{b}	119.63 ^{a}	96.87 ^{b}	128.43 ^{a}	96.03b	13.21
Absorbed Na(mg/g)	59.53 ^{a}	26.27 ^{b}	54.4 ^{a}	31.73 ^{b}	63.3 ^{a}	30.90 ^{b}	15.97
Liver							
Initial Na content(mg/g)	80.13	80.13	80.13	80.13	80.13	80.13	15.69
Final Na content(mg/g)	144.67 ^{a}	111.40 ^{b}	139.63 ^{a}	116.87 ^{b}	148.43 ^{a}	116.03 ^{b}	13.21
Absorbed Na (mg/g)	64.53 ^{a}	31.27 ^{b}	59.5 ^{a}	36.73 ^{b}	68.30 ^{a}	35.90 ^{b}	15.97

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, 4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Na= Sodium.

The blood and liver Na utilization is shown in Table 4.7. The result showed that sheep on T1, T3, and T5 with mineral supplementation absorbed 59.53, 54.40 and 63.3mg/g of Na respectively and differed significantly from those on T2, T4 and T6 with 26.27, 31.73 and 30.90mg/g of Na respectively. The result of the liver Na absorption showed that sheep on T1, T3, and T5 with mineral supplementation absorbed 64.53, 59.50 and 68.30mg/g of Na respectively and differed significantly from those on T2, T4 and T6 with 31.27, 36.73 and 35.90mg/g Na respectively. The high concentrations of Na amongst the treatment groups with supplementation of minerals could be as a result of inclusion of NaCl in their diet. Sowande *et al.* (2008) reported blood Mg concentration of 101.17±6.20 and 105.13±2.58mmol/L for WAD sheep grazing in wet and dry season respectively.

Table 4.8: Blood and liver Copper (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Cu content(mg/g)	173.23	173.23	173.23	173.23	173.23	173.23	20.08
Final Cu content(mg/g)	294.33^{a}	216.07^{b}	293.57^{a}	207.70^{bc}	289.83^{a}	183.63^{c}	26.70
Absorbed Cu(mg/g)	117.10^{a}	38.83^{b}	116.33^{a}	30.47^{b}	112.60^{a}	13.07^{b}	30.33
Liver							
Initial Cu content(mg/g)	207.33	207.33	207.33	207.33	207.33	200.567	20.08
Final Cu content(mg/g)	337.33^{a}	259.07^{b}	336.57^{a}	250.7^{bc}	332.83^{a}	226.637^{c}	26.70^{a}
Absorbed Cu(mg/g)	130.1^{a}	51.83^{b}	129.33^{a}	43.47^{b}	125.60^{a}	26.07^{b}	30.33

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Cu= copper.

Table 4.8 shows the blood and liver copper absorption by the experimental animals. The blood result showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 117.10, 116.33 and 112.60mg/g of Cu respectively and differed significantly from those on T2, T4 and T6 with 38.83, 30.47 and 13.07mg/g of Cu respectively. The result of the liver Cu absorption showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 130.10, 129.33 and 125.60mg/g of Cu respectively and differed significantly from those on T2, T4 and T6 with 51.83, 43.47 and 26.07mg/g of Cu respectively. The high absorption rate of Cu recorded for the treatment group with supplement could have occurred due inclusion of the mineral premix which contained lots of micro minerals including Cu that was being utilized by the animals. Lengarite *et al.* (2012) reported values of 184.07 and 303mg/g respectively for liver Cu concentration during the dry and wet season in three grazing sites of Kenya. The authors ascribed the high hepatic Cu in wet season to consumption of new plant tissues capable of extracting soil Cu.

Table 4.9: Blood and liver Iron (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Fe content(mg/g)	86.03	86.03	86.03	86.03	86.03	86.03	6.59
Final Fe content(mg/g)	203.67[a]	129.87[b]	216.77[a]	106.43[b]	222.10[a]	114.30[b]	25.03
Absorbed Fe(mg/g)	117.63[a]	43.83[b]	130.73[a]	20.40[b]	136.07[a]	28.27[b]	28.93
Liver							
Initial Fe content(mg/g)	108.03	108.03	108.03	108.03	108.03	108.03	6.59
Final Fe content(mg/g)	235.37[a]	161.87[b]	248.77[a]	138.43[b]	254.10[a]	146.30[b]	25.03
Absorbed Fe (mg/g)	127.63[a]	53.83[b]	140.73[a]	30.40[b]	146.07[a]	38.27[b]	28.93

Means with common superscript within a row do not differ. T1= Cenchrus hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover (50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Fe= Iron.

Table 4.9 shows the result of blood and liver Iron absorption by experimental animals. The blood result showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 117.63, 130.73 and 136.07mg/g of Fe respectively and differed significantly from those of T2, T4 and T6 with 43.83, 20.40 and 28.27mg/g of Fe respectively. The result of the liver Fe absorption showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 127.63, 140.73 and 146.07mg/g of Fe respectively and differed significantly from those on T2, T4 and T6 with 53.83, 30.40 and 38.27mg/g of Fe respectively. The treatment groups with mineral supplementation had higher blood concentration of Fe and could have been absorbed from the premix included in the diet. Lengarite *et al.* (2012) reported values of 187.04 and 213.11mg/g respectively for liver Cu concentration during the dry and wet season in three grazing sites of Kenya. The authors attributed the increase in liver Fe during the wet season to increased extraction of soil Fe by plants and thus elevated concentration of Fe in forages.

Table 4.10: Blood and liver Zinc (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Zn content(mg/g)	53.90	53.90	53.90	53.90	53.90	53.90	18.67
Final Zn content(mg/g)	88.7^{b}	58.23^{d}	100.87^{ab}	75.13^{c}	106.33^{a}	73.10^{c}	12.40
Absorbed Zn(mg/g)	34.80^{b}	6.87^{d}	46.97^{a}	21.23^{c}	52.43^{a}	19.20^{c}	12.04
Liver							
Initial Zn content(mg/g)	65.90	65.90	65.90	65.90	65.90	65.90	18.67
Final Zn content(mg/g)	103.70^{b}	73.23^{d}	115.87^{ab}	90.13^{c}	121.33^{a}	88.10^{c}	12.40
Absorbed Zn(mg/g)	37.80^{b}	7.33^{d}	49.97^{ab}	24.23^{c}	55.43^{a}	22.20^{c}	12.04

Means with common superscript within a row do not differ. T1= Cenchrus hay (50%) + supplements (50%) Control, T2 = Cenchrus hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover

(50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Zn= Zinc.

Table 4.10 shows the result of blood and liver Zinc absorbed by experimental animals. The blood result showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 34.80, 46.97 and 52.43mg/g of Zn respectively and differed significantly from those on T2, T4 and T6 with 6.87, 21.23 and 19.20mg/g of Zn respectively. The result of the liver Zn absorption showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 37.80, 49.97 and 55.43mg/g of Zn respectively and differed significantly from those sheep on T2, T4 and T6 with 7.33, 24.23 and 22.20mg/g of Zn respectively. The animals with the high rate of blood and liver Zn must have derived Zinc from the premix included in their diet. Lengarite *et al.* (2012) reported values of 83.34 and 94.11mg/kg respectively for liver Zn concentration during the dry and wet season in three grazing sites of Kenya.

Table 4.11: Blood and liver Manganese (mg/g) utilization of experimental animals

Mineral utilization	Types of treatment (LSM)						
	T1	T2	T3	T4	T5	T6	LSD
Blood							
Initial Mn content(mg/g)	3.83	3.83	3.83	3.83	3.83	3.83	1.43
Final Mn content(mg/g)	11.17^{a}	6.33^{b}	11.17^{a}	6.00^{b}	10.87^{a}	4.80^{c}	1.05
Absorbed Mn(mg/g)	7.33^{a}	2.50^{b}	7.33^{a}	2.17^{b}	7.03^{a}	0.97^{b}	1.55
Liver							
Initial Mn content(mg/g)	5.33	5.33	5.33	5.33	5.33	5.33	1.43
Final Mn content(mg/g)	14.97^{a}	10.13^{b}	14.97^{a}	9.43^{b}	14.67^{a}	7.77^{c}	1.05
Absorbed Mn(mg/g)	9.63^{a}	4.80^{b}	9.63^{a}	4.10^{bc}	9.33^{a}	2.43^{c}	1.55

Means with common superscript within a row do not differ. T1= Cenchrus .hay (50%) + supplements (50%) Control, T2 = Cenchrus .hay (50%) + supplements (50%) + mineral , T3 = Sorghum Stover (50%) + supplements(50%) +minerals, T4= Sorghum Stover (60%) + supplements (40%) +minerals , T5 = Millet Stover

(50%) + supplements(50%) + minerals, T6 = Millet Stover (60%) + supplements (40%) + minerals, LSM= least square means, LSD= least significant difference, Mn= Manganese.

The blood and liver Manganese absorbed by experimental animals are shown in Table 4.11. The blood result showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 7.33, 7.33 and 7.03mg/g of Mn respectively and differed significantly from those on T2, T4 and T6 with 2.50, 2.17 and 0.97mg/g of Mn respectively. The result of the liver Mn absorption showed that sheep on T1, T3, and T4 with mineral supplementation absorbed 9.63, 9.63 and 9.33mg/g of Mn respectively and differed significantly from those on T2, T4 and T6 with 4.80, 4.10 and 2.43 mg/g of Mn respectively. The animals with the high rate of blood and liver Mn must have derived Mn from the premix included in their diet and could have elevated the concentrations in both the blood and the liver. Lengarite *et al.* (2012) reported values of 7.54 and 13.24mg/kg respectively for liver Mn concentration during the dry and wet season in three grazing sites of Kenya.

4.5: Conclusion

Mineral supplementation had no effect on feed intake, feed conversion ratio, weight gain and carcass characteristics of Tswana sheep but had effects on blood and liver micro and mineral concentrations. Total mixed ration that had Sorghum Stover (50%) + supplements (50%) plus minerals produced higher feed intake, higher final weight, and lower feed conversion ratio (FCR) in Tswana sheep than other treatment groups. Despite the fact that there were no differences in the performance parameters, the feed conversion ratios and the average daily gains of the treatment groups with minerals were better than rations without mineral supplementation. Sheep feeding on rations containing Cenchrus hay plus mineral had the highest carcass weight followed by sheep feeding on rations containing Sorghum Stover plus minerals. High chuck blade weight was found in sheep that had high carcass weight, and low carcass weight produced less chuck blade weight. Treatment rations with mineral supplementation had both their blood and liver phosphorus, Magnesium, Sodium, Copper, and Iron level elevated.

4.6: Recommendations

Sorghum and millet stover be stored during harvest for incorporation into sheep diet during the dry season when the fields are bare and feed expensive. Minerals should be included in Tswana sheep diet in order to avert mineral deficiencies.

CHAPTER 5

5.0: REFERENCES

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