PRODUCTION CHARACTERISTICS, MANAGEMENT PRACTICES AND ON-FARM PHENOTYPIC CHARACTERISATION OF INDIGENOUS TSWANA SHEEP IN FOUR DISTRICTS OF SOUTHERN BOTSWANA

MASTER OF SCIENCE IN ANIMAL SCIENCE
(ANIMAL BREEDING AND REPRODUCTION)

MONOSI ANDRIES BOLOWE

August 2021

PRODUCTION CHARACTERISTICS, MANAGEMENT PRACTICES AND ON-FARM PHENOTYPIC CHARACTERISATION OF INDIGENOUS TSWANA SHEEP IN FOUR DISTRICTS OF SOUTHERN BOTSWANA

A dissertation submitted to the Department of Animal Sciences in partial fulfilment of the requirements for the degree of Master of Science (MSc) in Animal Science (Animal Breeding and Reproduction).

MONOSI ANDRIES BOLOWE

Faculty of Animal and Veterinary Sciences

Department of Animal Sciences

Botswana University of Agriculture and Natural Resources

Main supervisor: **Dr K. Thutwa**

Co-supervisors: **Prof. P.M Kgwatalala**

Dr. P.I Monau

Mr. C. Malejane

August 2021

DECLARATION

I, Monosi Andries Bolowe hereby declare that this dissertation submitted by me for the Master of Science degree (Animal Breeding and Reproduction) at the Botswana University of Agriculture and Natural Resources is my own original and independent work and has not been previously submitted by me to another University or Faculty to obtain any qualification. All assistance towards the production of this work and references contained herein have been duly acknowledged.

Monosi Andries Bolowe

APPROVAL

Main supervisor's name	Date	Signature
----------------------------------	--------------------------	--------------------------
Co-supervisor's names	Date	Signature
----------------------------------	--------------------------------	--------------------------
-----------------------------------	----------------------------------	---------------------------
-----------------------------------	---------------------------------	--------------------------
Head of Department's name	Date	Signature
------------------------------------	-----------------------------------	-------------------------

GENERAL ABSTRACT

In the framework of collecting information that will aid in development of breeding and conservation strategies and policies intended for the conservation of indigenous Tswana sheep in the Southern part of Botswana, a survey of production system and on-farm phenotypic characterization of indigenous Tswana sheep were undertaken in the Kgatleng, Kweneng, South-East and Southern districts. Multi-stage purposive and random sampling were employed as sampling techniques. Detailed structured questionnaires on farmers' socio-economic parameters, breeding and general management practices on Tswana sheep, field observations of animals, body measurements and secondary data collection were used to produce the data. Data on qualitative characters and quantitative measurements were made on 665 sheep stratified by dentition into four age categories of zero permanent pair of incisors (0PPI), one permanent pair of incisors (1PPI), two permanent pairs of incisors (2PPI) and three or more permanent pairs of incisors (≥3PPI) to represent age ranges of 6-11, 12–24, 25–36 and above 36 months, respectively. Qualitative survey data were analyzed using procedure frequencies of Statistical Package for Social Sciences while quantitative data were analyzed using Statistical Analysis System. Results revealed that the mean average flock sizes for Kgatleng, Kweneng, Southern and South-East were 22.20±3.8, 24.81±3.56, 30.08±3.77 and 23.58±3.77, respectively. Sheep played multifaceted roles for farmers across districts. Amongst the reasons for keeping sheep, Kgatleng and Kweneng district farmers primarily kept sheep for generating cash derived from sales (index= 0.480 and 0.390, respectively) and in the Southern and South-East districts farmers primarily kept sheep for ceremonial (socio-cultural) use (index=0.310 and 0.371, respectively). Competitive superiority of indigenous Tswana rams over their exotic counterparts in terms of survival and reproduction under Botswana environment was the most preferred trait when selecting breeding rams in Kgatleng (index= 0.290), Kweneng

(index= 0.301) and South-East (index= 0.247) while in Southern district breeding rams were mainly selected based on body size (index= 0.372). Castration of rams in Kgatleng, Kweneng and South-East districts was mostly done at 3-6 months while Southern district farmers castrated at a later age of 6-12 months.

The dominant coat color pattern on Tswana sheep was plain with most sheep having white dominant and plain white color coats. Most Tswana sheep had a characteristic feature of short fat tail with a straight tip, no wattles, no horns and almost all sheep (98.65%) had horizontal ear orientation. District, sex and age and the age by sex interaction had a significant ($P<0.05$) effect on body weight and most linear body measurements. The body weight and most linear body measurements of sheep increased gradually as the sheep advancement in age. Tswana males were generally heavier and superior than females in most linear body measurements. Indigenous Tswana sheep from the Southern district showed superiority in some features of economic importance such as body weight, body length and heart girth over other districts. The overall mean body weight, heart girth, body length, wither height, rump width, ear length, tail length, tail circumference, head length, head width, shoulder width, cannon bone length, cannon bone circumference, neck length, rump length, rump height and scrotum circumference (in males) across districts were 35.93±0.55 kg, 78.31±0.65, 62.17±0.53, 64.51±0.51, 15.98±0.20, 11.43±0.12, 21.67±0.63, 12.54±0.57, 13.15±0.13, 10.00±0.11, 21.79±0.33, 15.19±0.12, 7.51±0.52, 30.38±0.43, 23.56±0.28, 64.44±0.31 and 26.66±0.89 cm, respectively.

There were positive and significant correlations observed between body weight and most linear body measurements for both sexes. The highest correlation coefficient was found between body weight and heart girth for both sexes of Tswana sheep. The regression analysis to predict body weight from linear body measurements indicated that body weight prediction could be more

accurate when more than one independent variable was used. However, from a practical view point, the use of heart girth as a sole predictor for body weight was suggested since heart girth accounted for more variability than other linear body measurements for sexes and also due to its ease of measurement under farmers' conditions. The prediction of body weight for Tswana sheep was therefore based on the regression equations $y= -64.15+1.28x$ in males and $y= -53.47+1.14x$ for females where, x and y are heart girth and body weight respectively. This study reveals existence of diversity of sheep genetic resources across districts which needs to be verified at a molecular level.

Keywords: Body weight, breeding, characterization, correlation, phenotypic, Tswana sheep

DEDICATION

I dedicate this work to two most important people in my life; my mother (Ms. Boikobo Bolowe) for nursing me with affection and love and for her dedicated partnership in the success of my life. To my late father (Mr. Batshabeng Lekang, 1961-1999) you are forever engraved in my heart and you shall forever remain my hero. This is in honor of you for being part of my life.

ACKNOWLEDGEMENTS

I would like to thank the Almighty God for giving me the most precious gift of life and for giving me the grace and the strength to accomplish this study. To Him and Him alone, be all the glory.

I would like to extend my deepest and sincere appreciation to Dr. K. Thutwa (main supervisor), Prof. P.M Kgwatalala, Dr. P.I Monau and Mr. C. Malejane (co-supervisors) for their unreserved encouragement, constructive criticism, meticulous guidance, professional expertise and the conducive environment they created for me to complete this work. The knowledge they shared and approaches they displayed to tackle challenges during the study will not only apply to my professional carrier but my life as a whole. I am grateful to Barclays F.G Mogae Scholarship for paying my tuition fees to pursue my MSc study and the Botswana University of Agriculture and Natural Resources Research and Publication committee (RPC) -2020 (Project name: Tswana sheep) for financial support for the research work.

I am forever indebted to indigenous Tswana sheep owners in the Kgatleng, Kweneng, Southern and South-East districts of Botswana for their unreserved cooperation and willingness to allow their animals to be used for this study without hesitation. The time they took to share their knowledge and experiences during data collection will forever be valued. My sincere appreciation is also due for the Department of veterinary services staff in Kgatleng, Kweneng, Southern and South-East districts for their selfless assistance by liaising with farmers during data collection. A very special and sincere appreciation to Ms. Chandapiwa Moses, Ms. Malebogo Radikara and Mr. Bernard Letsholo for their selfless moral support and assistance in the handling of sheep during data collection. You went an extra mile. Thank you. To my other MSc colleagues and undergraduate students your support during the research period is highly appreciated.

I am greatly indebted to my mother (Ms. Boikobo Bolowe) for her endless prayers and financial assistance she helped me with when other financial resources dried up during the study period. Am grateful to my sister (Setshwano K.P Bolowe) for helping me during data entry and encouraging me to soldier on when the journey was getting tougher. My grandmother (Gabathuse Bolowe) and aunts (Boikhutso Lekang and Boingotlo Mbae and their families) I value your endless prayers and well wishes for me to succeed in my academics. You believed in me even during moments when I had lost hope, discouraged and could not believe in myself. Thank you.

TABLE OF CONTENTS

CONTENTS **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

AnGR	Animal Genetic Resource
APRU	Animal Production Research Unit
BW	Body weight
Cm	centimeter
Eg	Example
FAGR	Farm Animal Genetic Resources
FAO	Food and Agriculture Organization
Kg	Kilograms
LBMs	Linear Body Measurements
LIMID	Livestock Management and Infrastructure Development
SE	Standard error

CHAPTER 1

GENERAL INTRODUCTION

1.1. Background

Sheep have always played a pivotal role in the livelihood of smallholder farmers particularly in the rural areas of Botswana. They are kept for their economic, scientific and cultural value to mankind as well as agricultural production for the present and posterity (Gibson *et al*., 2006; Rege and Mwai, 2006). They are a nutrition source (meat and milk); they provide manure (non-commercial contributions) and are sold to generate cash for the smallholder families as need may arise. Sheep are among the small ruminants used in various religious activities (Molotsi *et al*., 2019) and socio-cultural purposes such as dowry payment (Kunene *et al*., 2009; Aganga and Aganga, 2015).

Sheep as an animal genetic resource form an important component of biodiversity because the efforts to improve national food security in developing countries lies in the wise use of their genetic diversity (Philipsson *et al*., 2011). Sheep can easily be integrated into an established farm and are a good complement to cattle. It has been demonstrated that grazing sheep with cattle can increase total meat production by up to 24% more meat in cattle compared to raising cattle alone and by up to 9% more mutton in sheep compared to when sheep were raised alone (Hale *et al*., 2010). Integrating sheep into a farming operation can thus also contribute to the economic and environmental sustainability of the whole farm. This is because sheep will enhance a farm's biological diversity and may fit economic and biological niches that would otherwise go unfilled in the farm (Hale *et al*., 2010).

The sheep population in Botswana is at just under 300,000 with the indigenous Tswana sheep dominating the national flock by around 65% (Statistics Botswana, 2016). Tswana sheep have been described as medium sized breed on the basis of body weight and height at withers (APRU, 1984). They are mostly kept in communal traditional management systems characterized by low inputs into production (Monau *et al*., 2017) and are kept in small livestock units per unit area (Tavirimirwa *et al*., 2013). It is classified as a meat breed since it does not produce wool and their milk is not harvested for human consumption (Nsoso *et al*., 2004b). The indigenous Tswana sheep genetic resources are mostly kept in hot and often dry environment with cold winter nights (Makhabu *et al*., 2002). They retain certain adaptive features which make them well adapted to harsh environmental factors hence are highly resilient to a wide range of agro-ecological conditions (Nsoso *et al*., 2004b). These include diverse adverse climatic conditions, poor and seasonal feed sources, shortage of water, endemic diseases such as tick-bone diseases and internal parasites (Monau *et al*., 2018). Under such environmental conditions, the competitive performance of Tswana sheep with regards to survival and production is reported to be better than of its exotic counterparts such as Dorper (Government of Botswana, 2011). The same has generally been reported for most indigenous breeds. For example, the Zulu sheep are reported to be highly tolerant to tick borne diseases and internal parasites and also have good walking and foraging ability (Kunene *et al*., 2009). The indigenous sheep are thus more suitable for use in the traditional, communal systems where there is low-external-input production system (Hailemariam *et al*., 2018). The unique characteristic features make the indigenous Tswana sheep breed an important and a good animal genetic resource (AnGR) for improvement, conservation and future sustainable utilization (Nsoso *et al*., 2004b).

The need to develop realistic breed improvement programs that will ensure improvement, conservation and sustainable utilization of these valuable AnGR cannot therefore be over emphasized. The prerequisite to developing these strategies is characterization of the Tswana sheep genetic resource under its natural environment (Msanga *et al*., 2012; Monau *et al*., 2018). Characterization of AnGR entails all activities associated with the identification, quantitative and qualitative description, and documentation of breed populations and the natural habitats and production systems to which they are or are not adapted (Rege, 1994). The benefits of characterization includes provision of relevant information needed to formulate policies that govern informed decisions on priorities for the management and conservation of the AnGR particularly indigenous genetic resources (Hanotte and Jianlin, 2005). Indigenous livestock are a source of genetic diversity that is needed by modern livestock production to ensure stability and continuity (Asefa *et al*., 2017).

1.2. Problem Statement

There is a general concern regarding animal genetic diversity especially indigenous breeds in developing countries. Their populations are threatened by indiscriminate crossbreeding by use of improved strains or breeds (Van Marle-Koster *et al*., 2015) in pursuit of taking advantage of breed complementarity and heterosis effects (Zobell *et al*., 2019) to meet high animal production demand. This is done without prior giving adequate attention to evaluating and setting realistic and optimum breeding objectives before embarking on breed improvement programmes (Rege and Lipner, 1992). Furthermore, farmer's breeding goals are now focused on a few economically important traits of high market value such as meat proportion using exotic breeds. This leaves many of the functional traits (deeply rooted within indigenous breeds as the Tswana sheep such as health, fertility or longevity) to carry less weight (Belew *et al*., 2016). This eventually leads to replacement of locally adapted breeds by high-yielding international or transboundary breeds (Agaviezor *et al*., 2012) before they are characterized. This is due to lack of policies, strategies and breeding programmes that could guide farmers on the management conservation and sustained utilization of these AnGR. Indiscriminate crossbreeding contributes to severe genetic erosion, threatens both the innate characteristics (disease resistance, adaptation to survive and reproduce under harsh environmental conditions etc.) and the eventual existence of the once adapted Tswana sheep by the less adapted exotic breeds and their crosses that are of high maintenance costs to resource poor farmers (Nsoso *et al*., 2004b; Monau *et al*., 2017).

1.3. Justification

Despite low levels of productivity, attributable to several factors such as genotype, institutional, environmental and infrastructural constraints, indigenous sheep breeds have a great potential to contribute more to the livelihood of people in low input, smallholder, and pastoral production systems (Kosgey and Okeyo, 2007). In the era of changing climatic conditions due to global warming coupled with increases in the number of health-conscious consumers who prefer grass fed mutton, the hardy and resilient indigenous Tswana sheep stands as a sheep of choice to meet the changing production environment and market demands. Characterization of Tswana sheep will provide information that will be used to inform and guide policy developers to devise strategies and policies intended for the management (including improved productivity), conservation and sustained utilization of AnGR. This will ensure sustainable breed utilization and continued improvement in the livelihoods of resource poor farmers keeping this breed, alleviating them from poverty. Furthermore, characterization also provides an opportunity for conservation, routine inventory and monitoring of indigenous Tswana sheep genetic resources.

1.4. General objective

The overall objective of this study was to describe the production system and carry an on-farm phenotypic characterization of indigenous Tswana sheep in the Kgatleng, Kweneng, Southern and South-East districts of Botswana.

1.4.1. Specific objectives

The specific objectives of this study were:

1) To describe existing indigenous Tswana sheep production systems, management practices and farmers preferred traits when selecting breeding rams in the Kgatleng, Kweneng, Southern and South-East districts of Botswana, using survey data.

2) To phenotypically characterize indigenous Tswana sheep under its native environment and to develop a prediction equation for body weight estimation on Tswana sheep using linear body measurements in the Kgatleng, Kweneng, Southern and South-East districts of Botswana.

1.5. References

Aganga, A. O. and Aganga, A. A. (2015). Quality Assurance in Goat Meat Production for Food Safety in Botswana. *Asian Journal of Biological Sciences* 8(2):51–56.

Agaviezor, B. O., Peters, S. O., Adefenwa, M. A., Yakubu, A., Adebambo, O. A., Ozoje, M. O., Ikeobi, C. O. N., Wheto, M., Ajayi, O. O., Amusan, S. A., Ekundayo, O. J., Sanni, T. M., Okpeku, M., Onasanya, G. O., De Donato, M., Ilori, B. M., Kizilkaya, K. and Imumorin, I.G. (2012). Morphological and microsatellite DNA diversity of Nigerian indigenous sheep. *Journal of Animal Science and Biotechnology* 3(1):1-16.

APRU, (1984). Livestok and range research in Botswana. 1983-1984. Animal Production Researh Unit: Gaborone, Botswana.

Asefa, B., Abate, T. and Adunga, E. (2017). Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. *Journal of Veterinary Science and Technology* 8 (4):1-7.

Belew, A. K., Tesfaye, K. and Belay, G. (2016). The State of Conservation of Animal Genetic Resources in Developing Countries: A Review. *International Journal of Pharma Medicine and Biological Sciences* 5(1):58–66.

Gibson, J., Gamage, S., Hanotte, O., Iñiguez, L., Maillard, J. C., Rischkowsky, B., Semambo, D. and Toll, J. (2006). Options and strategies for the conservation of farm animal genetic resources: Report of an International workshop. AGROPOLIS, (7–10 November 2005, Montpellier, France).

Government of Botswana. (2011). Small Stock Management Practices. Retrieved September 19, 2019, from https://.www.gov.bw/en/Ministries--Authorities/Ministries/ Ministry of Agriculture-Moa/Tools--Services/Livestok/Small-Stock-Management-Practices.

Hailemariam, F., Gebremicheal, D. and Hadgu, H. (2018). Phenotypic characterization of sheep breeds in Gamogofa zone. *Agriculture and Food Security* 7(1):1–7.

Hale, M., Coffey, L., Bartlett, A. and Ahrens, C. (2010). Sheep: Sustainable and Organic Production. *Appropriate Technology*. p24.

Hanotte, O. and Jianlin, H. (2005). Genetic characterization of livestock populations and its use in conservation decision making. *The Role of Biotechnology in Exploring and Protecting Genetic Resources*, 5-7 *March*. 131–136.

Kosgey, I. S. and Okeyo, A. M. (2007). Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant Research* 70(1):76–88.

Kunene, N. W., Bezuidenhout, C. C. and Nsahlai, I. V. (2009). Genetic and phenotypic diversity in Zulu sheep populations: Implications for exploitation and conservation. *Small Ruminant Research* 84(1–3):100–107.

Molotsi, A. H., Dube, B. and Cloete, S. W. P. (2019). The current status of indigenous Ovine genetic resources in Southern Africa and future sustainable utilisation to improve livelihoods. *Diversity* 12(1):1-16.

Monau, P. I., Visser, C., Nsoso, S. J. and Van Marle-Köster, E. (2017). A survey analysis of indigenous goat production in communal farming systems of Botswana. *Tropical Animal*

Health and Production 49(6):1265–1271.

Monau, P. I., Visser, C., Nsoso, S.J. and Van Marle-Köster, E. (2018). Phenotypic and genetic characterization of indigenous Tswana goats. *South African Journal of Animal Science*, 48(5):925-934.

Msanga, Y. N., Mwakilembe, P. L. and Sendalo, D. (2012). The indigenous cattle of the Southern Highlands of Tanzania: distinct phenotypic features, performance and uses. *Livestock Research for Rural Development* 24(7).

Nsoso, S. J., Podisi, B., Otsogile, E., Mokhutshwane, B. S., and Ahmadu, B. (2004b). Phenotypic Characterization of Indigenous Tswana Goats and Sheep Breeds in Botswana: Continuous Traits. *Tropical Animal Health and Production* 36(8):789–800.

Philipsson, J., Rege, J., Zonabend, E. and Okeyo, A. M. (2011). Sustainable breeding programmes for tropical low- and medium input farming systems In: Animal genetics training resource, version 3, 2011. Ojango, J. M., Malmfors, B. and Okeyo, A. M. (Eds). *Animal Genetics Training Resource, Version 3, 2011. Ojango, J.M., Malmfors, B. and Okeyo, A.M. (Eds). International Livestock Research Institute,* 1-35. Nairobi, Kenya, and Swedish University of Agricultural Sciences, Uppsala, Sweden.

Rege, J. E. O. (1994). Indigenous African small ruminants: a case for characterisation and improvement. In Small Ruminant Research and Development in Africa. *Proceedings of the Second Biennial Conference of the African Small Ruminant Research Network*, pp. 205–211.

Rege, J. E. O. and Mwai, A. O. (2006). Improving our knowledge of tropical indigenous animal genetic resources. *Animal Genetics Training Resource*. 28.

Rege, J. E. O. and Lipner, M. E. (1992). African Animal Genetic Resources: their Characterisation, Conservation and Utilisation. In; *Proceedings of the Researh Planning Workshop, ILCA.* 19th -21st February 1992. Addis Ababa, Ethiopia.

Statistics Botswna, (2016). Agricultural census stats brief of 2015. Gaborone, Botswana http://www.statsbots.org.bw/sites/default/files/Botswana Agriculture Census Report Final 2015..pdf

Tavirimirwa, B., Mwembe, R., Ngulube, B., Banana, N. Y. D., Nyamushamba, G. B., Ncube, S. and Nkomboni, D. (2013). Communal cattle production in Zimbabwe: *A. Development,* 25:12.

Van Marle-Koster, E., Visse, C., Makgahlela, M. and Cloete, S. W .P. (2015). Genomic technologies for food security: A review of challenges and opportunities in Southern Africa. *Food Resources International* 76: 971-979.

Zobell, D., Chapman, C. K. and Despain, D. (2019). Applying principles of crossbreeding to maximise Hybrid Vigor. *Animal Health,* Utah State University. Retrieved from https://www.extension.usu.edu

CHAPTER 2

LITERATURE REVIEW

2.1. Origin and domestication of sheep

Sheep belong to the family Bovidae, sub-family Caprinae, and genus *Ovis*. The genus *Ovis* includes both the domesticated sheep and their wild ancestors. The wild sheep originates in the mountain ranges of Central Asia and they spread westwards into Europe and eastwards into North America during the Pleistocene period (Ryder, 1984). They were among the first animals to be domesticated from at least three ancestral subspecies of the wild Mouflon (*O. gmelini*) (Ryder, 1984; Hiendleder *et al*., 2002) around 11 000 years ago in the Fertile Crescent (Zeder, 2008). To distinguish domestic sheep from their wild relatives, domestic sheep are now classified as *Ovis aries* (Zewdu, 2008). Today, sheep (*Ovis aries*) are geographically well distributed globally and are important to the rural dwellers especially in the tropics (Parmatma, 1986). Ever since domestication they have been exposed to different intensities of evolutionary forces such as natural and artificial selection, mutation, migration, and random genetic drift as they were transported and migrated throughout Europe (Guo *et al*., 2005; Lawson-Handley *et al*., 2007). These migrations gave rise to differences within their genomes and phenotypes (Hanotte and Jianlin, 2005). Consequently, diverse local breeds with unique composition of various traits were developed (Guo *et al*., 2005). The developed breeds were then improved by well-planned breeding objectives efforts to present breeds distinct to a locality (Kawęcka *et al*., 2016).

As of 2006, over 850 sheep breeds were recognized internationally (Lawson-Handley *et al*., 2007) and today, the population of sheep across the globe is approximately more than 1.2 billion sheep with 19% of these found in Asia and Africa (FAOSTAT, 2016). Most of the sheep in Africa have been naturally selected to particular environments over years and are thus indigenous to their localities. They are mostly named after their localities. For example indigenous sheep native to KwaZulu-Natal in South Africa are called Zulu sheep, Damara sheep were named from the specific region where the sheep were originally found, the gross Damaraland (Almeida, 2011) and similarly those indigenous to Botswana are indigenous Tswana sheep. Indigenous sheep possess valuable traits that have never been exploited. The existence of these indigenous sheep is however, threatened by industrialization, lack of breeding policies and unplanned crossbreeding (Kogsey and Okeyo, 2007). These factors subsequently limit the utilization and conservation of these animal genetic resources. This therefore emphasizes the urgent need to formulate conservation measures to conserve such breed populations.

2.2. Importance of sheep in Botswana

The importance of sheep in Botswana cannot be overstated. They significantly contribute to the livelihoods of resource poor farmers as a nutrition resource and are sold to generate income which is used for a wide array of economic activities in the households of resource poor farmers (Nsoso *et al*., 2004b). Sheep are used for paying bride price (*bogadi*) (Aganga and Aganga, 2015) and to resolve conflicts (as fine) in the villages, this is a fulfilment of socio-cultural obligations especially in the Southern part of Botswana (Baleseng *et al*., 2016). Sheep are also given as a token of appreciation to friends, guests and family members, and used for special ceremonies such as weddings, funerals, circumcision and ancestral appeasement (Katongole *et al*., 1996). Derived from their biblical ancient use, sheep also play an important role in spiritual cleansing ceremonies such as exorcism of evil spirits and are given as a sacrifice to calm down avenging spirits (Magangana *et al*., 2015).

2.3. Overview of sheep population in Botswana

In Botswana, the indigenous sheep constitute about 195 000 (65%) of the 300 000 national flock (Statistics Botswana, 2015). Other sheep breeds are only important for cross breeding with Tswana and Karakul being Doper, black Persian and Namaqua Afrikaner (Nsoso and Madimabe, 1999). Indigenous Tswana sheep are widely distributed across different agro ecological regions where they provide income, quality food and fertilizer (Baleseng *et al*., 2016) and also serve to improve livelihoods of people in rural areas by alleviating poverty (Nsoso *et al*., 2004b). However, the 2014/15 census on sheep population in Botswana revealed a decline in the numbers of indigenous Tswana sheep and a rise of exotic breeds' populations and their crosses (Figure 2.1). This decline is of great concern more so that Tswana sheep have not been adequately characterized, especially genetically. It is not even known if they present a single breed or several distinct breeds or strains within a similar breed. Indigenous sheep have generally received low attention in research compared to other indigenous domestic animals like goats and poultry. These therefore calls for more efforts to be put into indigenous sheep production in Botswana.

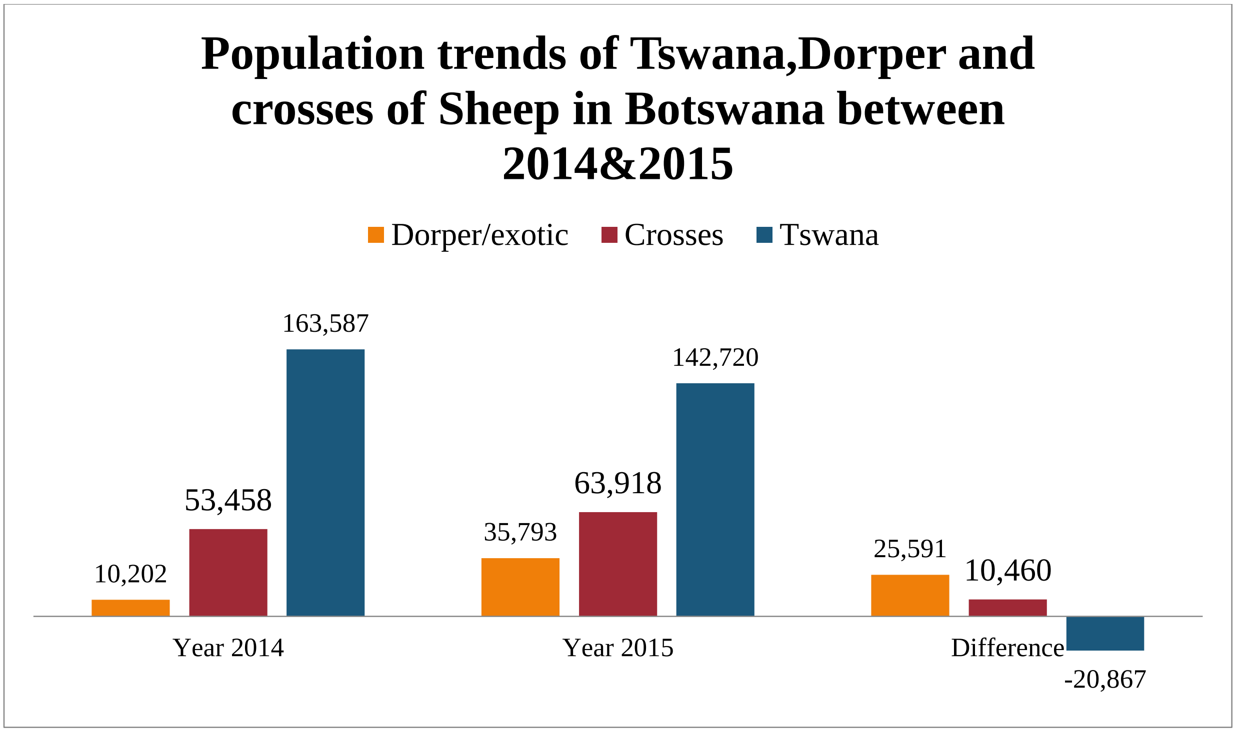

Figure 2.1: Sheep population trends over 2014 and 2015 in Botswana

Data used retrieved from: Statistics Botswana (2016).

2.4. Characterization as a basis for conservation decision making

Characterizing of AnGR, is an important prerequisite in development of proper breeding schemes that facilitate conservation and sustainable utilization of breeds (Food and Agriculture Organization (FAO, 2011). Characterization of Farm Animal Genetic Resources (FAGR) encompasses all clearly defined and described activities associated with the identification, quantitative and qualitative description, and documentation of breed populations (Food and Agriculture Organization (FAO), 2011). It entails monitoring and defining the size, structure and the geographical distributions of FAGR in their natural habitats and production systems to which they are predominantly found which influence their performance levels (Rege and Okeyo, 2006; Gizaw *et al*., 2011). Characterization thus intends to ensure that breed populations and their unique innate characteristics are not diluted or lost before their values are described and documented

(Rege and Lipner, 1992). Documentation of breed characteristics provide comprehensive knowledge about the current status and genetic structure of the breed, its production environment and diversity (Groeneveld *et al*., 2010). It provides relevant information that guides policy developers in formulating relevant policies and strategies that will govern stakeholders to conservation on priority areas in the management and conservation of AnGR particularly indigenous genetic resources (Hanotte & Jianlin, 2005).

The approach to conservation of indigenous AnGR therefore, has to be such that it incorporates collaborated components such as monitoring and characterization of AnGR to establish the degree of diversity (Woolliams *et al*., 2008). This will then guide preservation, maintenance, improvement and sustainable utilization (FAO, 2011). Characterization of AnGR is guided by descriptor list formulated and published by FAO (2011). The descriptor list serves to facilitate a valid comparison, classification or enumeration of breeds within a species in the context of the environments existing in the different countries and regions (Rege, 1994).

In Botswana, there was a characterization study conducted on sheep close to two decades ago (Nsoso *et al*., 2004b). It is vital to update previous results since genetic resources and production systems are not static (Sölkner *et al*., 1998). There is also need to carry out routine inventories and on-going monitoring of this breed. Thus there is a need for a more detailed characterization of indigenous Tswana sheep.

2.5. Characterization of production systems

Understanding the production system of livestock species which includes; indigenous knowledge on selection, management and identification of breeding goals is important for establishment of genetic improvement programs for small-holder and pastoral farmers (Kogsey *et al*., 2006b). In developing countries including Botswana, there are two most common production systems in the livestock sector; the commercial and the traditional production system (Monau *et al*., 2018). The latter is practiced on communal or tribal land where there is limited application of recommended livestock management practices primarily no fencing. Since there is no fencing, movement of livestock is not restrained and thus possibilities of uncontrolled breeding which could lead to inbreeding are high (Nsoso and Madimabe, 1999). This has been attributed to low literacy levels of farmers and inherited history of livestock keeping practices by livestock owners (Mthi and Ngangiwe, 2018). Contrary to the traditional production system, in commercial or freehold land there is fencing which makes controlled breeding achievable.

Most domesticated livestock populations in Southern Africa are dominated by indigenous breeds kept in small-scale traditional production systems in communal areas (Gwaze *et al*., 2009). They are mainly kept by resource poor farmers (Baleseng *et al*., 2016) and are subsistence oriented to fulfil multiple functions aimed at contributing to household food security (Mthi and Ngangiwe, 2018; Gwaze *et al*., 2009). Small-scale traditional production system is usually characterized by small number of livestock kept per unit area (Tavirimirwa *et al*., 2013), which require low inputs (shelter, supplementary feeding and modern medication) into production (Lebbie, 2004). This yields low production output levels to serve subsistence purposes like food sources and source of manure (Mthi and Ngangiwe, 2018). Other notable characteristics of this system include not keeping of records by farmers, informal labor derived from family members, (Abegaz, 2007; Nsoso *et al*., 2004b) and no defined breeding strategies and goals (Kogsey *et al*., 2006). This production system is hindered by major constraints such as high disease and parasite prevalence, predators, shortage of water and grazing land, which is the major feed resource (Gwaze *et al*., 2009). Almost all sheep production in Botswana takes place in the traditional smallholder sector and commercial livestock production is mainly focused on cattle (Baleseng *et al*., 2016; Burgess, 2006), especially in the western part of Botswana (Monau *et al*., 2017).

In Botswana, studies that described the sheep production systems and management practices are not only scarce but were also limited in their scope to provide an in depth analysis of the sheep production systems and define breeding objectives for indigenous Tswana sheep. Thus, more detailed characterization of the production system of indigenous Tswana sheep are required.

2.6. Phenotypic characterization

Phenotypic characterization entails conventional description of breeds based on their phenotype. This includes description of their external appearance (e.g. coat color, horns, beards, ear type and shape), linear body measurements (e.g. body length, heart girth, ear length, tail length), production traits (e.g. body weight, carcass weight, milk yield) and reproductive traits (e.g. age at first service, number of litters) (FAO, 2011; Monau *et al*., 2018). Phenotypic characterization is thus used to identify and document diversity within and between breeds based on their observable characters which are the morphological markers (Hailu and Getu, 2015). It is a tool for breed characterization influenced by the genetic complexity of an animal and the environment in which a breed is raised under (Gizaw *et al*., 2011), summed up into the equation; P=G+E where P is the phenotype, G is the genotype and E is the environment (Asefa *et al*., 2017; Pervage *et al*., 2009e). These factors allows an animal to survive and thrive to its maximum genetic potential in a particular environment. For example, sheep breeds in Gamogofa zone in Ethiopia were observed to have a black color dominating sheep flocks in the cold areas of the zone (Hailemariam *et al*., 2018). The black coat helps in the absorption of solar radiation thereby helping in maintaining body temperature of the animals to survive and reproduce to their full genetic potential.

Linear body measurements for selected characters (heart girth, height at withers, scrotum circumference, head width, head length, body length, pelvic width, shoulder width and ear length) have been used in morphological studies to phenotypically characterize small ruminants including; the South African Namaqua Afrikaner sheep breed of South Africa (Qwabe, 2011), indigenous Tswana sheep in Botswana (Nsoso *et al*., 2004b), sheep breeds in Gamogofa zone (Hailemariam *et al*., 2018) and indigenous sheep types of Northern Ethiopia (Michael *et al*., 2016). They provide the morphometric information for phenotypic characterization.

2.7. Prediction of live body weight using linear body measurements

Various linear body measurements such as heart girth, wither height and body length have been established to be positively correlated to live body weight (Rahman *et al*., 2008). This is done by regressing body weight over independent variables, which have higher correlation with body weight, in order to set an adequate model for the prediction of body weight separately for each sex (Asaminew *et al.,* 2016). This phenomenon has thus since been used for prediction of live weight in different sheep breeds (Afolayan *et al*., 2006; Taye *et al*., 2012; Pesmen and Yardimci, 2008). Therefore, body measurements are considered the basis for the establishment of further advanced characterization and the eventual selection of appropriate conservation strategies for indigenous sheep breeds (Yakubu and Ibrahim, 2011). The morphometric information generated from body measurements aids conservationists in assessment of type, function and market value of an animal (Hailemariam *et al*., 2018) as well as in selection of parent stock and animal husbandry practices such as drug administration. Agaviezor *et al*., (2012) reported that body measurements predominantly, heart girth, height at withers and body length can be used to aid selection of large size animals in the field.

Body measurements are therefore an indicator which reflects the body structure (phenotype) as it changes throughout the growth of an animal (Nsoso *et al*., 2004b; Hailemariam *et al*., 2018) and as influenced by their production environment among other factors. For example, Kunene *et al*., (2009) used body measurements to report diverse morphological characteristics of Zulu sheep which could be due to broad ancestral genetic pool of this breed. An enormous application potential of use of linear body measurements for phenotypic characterization of indigenous sheep and breed improvement potential has been demonstrated in several studies (Table 2.1).

Table 2.1 Some of phenotypic characterization studies on sheep breeds world-wide

Sheep breeds and Country	**District/region and number of sheep studied**	**Title of Study**	**Reference**
Indigenous Tswana goats and sheep (Botswana)	2783 goats and 1282 sheep All districts of Botswana	Phenotypic characterization of Indigenous Tswana Goats and sheep breed	(Nsoso *et al*., 2004b
Nguni sheep (South Africa)	100 sheep from Mhlathuze district in northern KwaZulu-Natal	Genetic and Phenotypic diversity in Nguni sheep populations	(Kunene *et al*., 2009)
Ganjam sheep (India)	604 sheep from Orissa State in the eastern region of India	Morphological and genetic characterization of Ganjam sheep	(Arora *et al*., 2010)
West African dwarf sheep Type (West Africa-Nigeria)	1080 sheep from three agricultural zones of Abi State, South East, Nigeria	Application of categorical traits in the assessment of breed and performance of sheep in a humid tropic	(Oke and Ogbonnaya, 2011)

2.8. References

Abegaz, S. G. (2007). In situ characterization of Gumuz sheep under farmer's management in North Western lowland of Amhara region. M.Sc. Thesis, Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Afolayan, R. A., Adeyinka, I. A. and Lakpini, C. A. M. (2006). The estimation of live weight from body measurements in Yankasa sheep. *Czech Journal of Animal Science* 51(8): 343–348.

Aganga, A.O. and Aganga, A.A. (2015). Quality Assurance in Goat Meat Production for Food Safety in Botswana. *Asian Journal of Biological Sciences* 8(2):51–56.

Agaviezor, B. O., Peters, S. O., Adefenwa, M. A., Yakubu, A., Adebambo, O. A., Ozoje, M. O., Ikeobi, C. O. N., Wheto, M., Ajayi, O. O., Amusan, S. A., Ekundayo, O. J., Sanni, T. M., Okpeku, M., Onasanya, G. O., De Donato, M., Ilori, B. M., Kizilkaya, K. and Imumorin, I.G. (2012). Morphological and microsatellite DNA diversity of Nigerian indigenous sheep. *Journal of Animal Science and Biotechnology* 3(1):1-16.

Almeida, A. (2011). The Damara in the context of Southern Africa fat-tailed sheep breeds. *Tropical animal health and production* 43:1427-41.

Arora, R., Bhatia, S. and Jain, A. (2010). Morphological and genetic characterization of Ganjam sheep. *Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales* 46:1–9.

Asaminew, M., Kebede, K. and Mekasha, Y. (2016). On farm phenotypic characterization of indigenous sheep types in Woliata Zone, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare* 6(11):114-124.

Asefa, B., Abate, T. and Adunga, E. (2017). Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. *Journal of Veterinary Science and Technology* 8 (4):1-7.

Baleseng, L., Kgosikoma, E. O. and Makgekgenene, A. (2016). Perfomance of goats and sheep under communal grazing in Botswana using various growth measures. In *Proceedings of ICAS V11 Seventh International Conference on Agricultural Statistics*.24th-26th. October 2016. Rome. doi:10.1481/icasV11.2016.b07

Burgess, S. (2006). Country Pasture/ Forage Resource Profiles: Botswana. Food and Agriculture Organization of the United Nations. Retrieved 14 April 2020, from http://www.fao.org/ag/agp/agpc/doc/counprof/PDF%20files/Botswana,pdf

Food and Agriculture Organization Statistics (FAOSTAT). (2016). Available at http://www.fao.org/faostat

Food and Agriculture Organization (FAO), (2011). Draft guidelines on molecular genetic characterization of animal genetic resources. *Commission on Genetic Resources for Food and Agriculture*, FAO, Rome, (April).

Gizaw, S., Komen, J., Hanotte, O., van Arendonk, J. A. M., Kemp, B., Mwai, O. and Dessie, T. (2011). Characterization and conservation of indigenous sheep genetic resources: A practical framework for developing countries. (Vol. 27). ILRI (aka ILCA and ILRAD). Available at: https://hdl.handle.net/10568/5371 (Accessed: 5 March 2020).

Groeneveld, L. F., Lenstra, J. A., Eding, H., Toro, M. A., Scherf, B., Pilling, D., Negrini, R., Finlay, E. K., Jianlin, H., Groeneveld, E. and Weigend, S. (2010). The GLOBALDIV Consortium. Genetic diversity in farm animals – A review. *Animal Genetics* 41:6-31.

Guo, J., Du, L. X., Ma, Y. H., Guan, W. J., Li, H. B., Zhao, Q. J., Li, X. and Rao, S. Q. (2005). A novel maternal lineage revealed in sheep (Ovis aries). *Animal Genetics*. 36(4):331–336.

Gwaze, F. R., Chimonyo, M. and Dzama, K. (2009). Communal goat production in Southern Africa: a review. *Tropical Animal Health and Production* 41(7):1157.

Hailemariam, F., Gebremicheal, D. and Hadgu, H. (2018). Phenotypic characterization of sheep breeds in Gamogofa zone. *Agriculture and Food Security* 7(1):1–7.

Hailu, A. and Getu, A. (2015). Breed Characterization: Tools and Their Applications. *A NewnOpen Access Journal* 2(4):1–9.

Hanotte, O. and Jianlin, H. (2005). Genetic characterization of livestock populations and its use in conservation decision making. *The role of biotechnology in exploring and protecting genetic resources*. Food and Agriculture Organization of the United Nations, Turin, Italy, pp. 131-136.

Hiendleder, S., Mainz, K., Plante, Y. and Lewalski, H. (2002). Analysis of mitochondrial DNA indicates that domestic sheep are derived from two different ancestral maternal sources: No evidence for contributions from Urial and Arali sheep. *Journal of Heredity* 89(2):113-20.

Katongole, J. B. D., Sebolai, B. and Madimabe, M. (1996). Morphological characterization of the Tswana goat. In: S.H.B Lebbie, & E. Kagwari (ed). *Small ruminant research and development in Africa.* Proc. 3rd Biennial Conference of the African Small Ruminant Research Network, UICC, Kampala, Uganda,5-9 December 1994, pp. 43–46.

Kawęcka, A., Gurgul, A. and Miksza-Cybulska, A. (2016). The use of SNP microarrays for biodiversity studies of sheep - A review. *Annals of Animal Science* 16(4): 975–987.

Kosgey, I. S. and Okeyo, A. M. (2007). Genetic improvement of small ruminants in low-input, smallholder production systems: Technical and infrastructural issues. *Small Ruminant Research* 70(1):76–88.

Kosgey, I. S., Baker, R. L., Udo, H. M. J. and Van Arendonk, J. A. M. (2006). Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research* 61(1):13-28.

Kunene, N. W., Bezuidenhout, C. C. and Nsahlai, I. V. (2009). Genetic and phenotypic diversity in Zulu sheep populations: Implications for exploitation and conservation. *Small Ruminant Research* 84(1–3):100–107.

Lawson-Handley, L., Byrne, K., Santucci, F., Townsend, S., Taylor, M., Bruford, M. W. and Hewitt, G. M. (2007). Genetic structure of European sheep breeds. *Heredity* 99(6):620–631.

Lebbie, S. H. (2004). Goats under household conditions. *Small Ruminant Research* 51(2):131-136.

Magangana, S., Gantsho, S., Mkhululi, V., Van Rooyen, T. and Palmer, O. (2015). The provisioning and cultural services of livestock in a small South African town. Available at: http://www.ru.ac.za/rhodesuniversity/content/environmentalscience/documents/.

Michael, A., Kefelegn, K. and Yoseph, M. (2016). Phenotypic characterization of indigenous Sheep types in Northern Ethiopia. *Journal of Natural Sciences Research*. 6(15):16–27.

Monau, P. I., Visser, C., Nsoso, S. J. and van Marle-Koster, E. (2017). A survey analysis of indigenous goat production in communal farming systems of Botswana. *Tropical Animal Health and Production* 49(6):1265–1271.

Monau, P. I., Visser, C., Nsoso, S. J. and Van Marle-Köster, E. (2018). Phenotypic and genetic characterization of indigenous Tswana goats. *South African Journal of Animal Science* 48(5):925-934.

Mthi, S. and Nyangiwe, N. (2018). Farmer's perception on sheep production constraints in the communal grazing areas of the Eastern Cape Province, South Africa. *International Journal of Livestock Production*. 9(12):334-339.

Nsoso, S. J. and Madimabe, M. J. (1999). The sheep industry in Botswana: Promoting the Karakul sheep industry. *South African Journal of Animal Science* 29(3):258-262.

Nsoso, S. J., Podisi, B., Otsogile, E., Mokhutshwane, B. S. and Ahmadu, B. (2004b). Phenotypic characterization of indigenous Tswana goats and sheep breeds in Botswana: Continuous traits. *Tropical Animal health and Production* 36(8):789-800.

Oke, U. M. and Ogbonnaya, E. O. (2011). Application of Categorical Traits in the Assessment of Breed and Performance of Sheep in a Humid Tropical Environment. *Livestock Research for Rural Development*. 23(25).

Parmatma, S. (1986). Sheep Production in the Tropics (Book Review). *Indian Journal of Agricultural Economics* 41(1):85.

Pervage, S., Ershaduzzaman, M., Talukder, M. A. I., Hasan, M. N. and Khandoker M. A. M. Y (2009). Phenotypic characterisation of indigenous sheep of Bangladesh. *Bangladesh Journal of Animal Science.* 38 (1&2):1-6.

Pesmen, G. and Yardimci, M. (2008). Estimating the live weight using some body measurements in Saanen goats. *Archiva Zootechnica* 11(4):30–40.

Qwabe, S. O. (2011). Genetic and phenotypic characterisation of the South African Namaqua Afrikaner sheep breed. Master's thesis. Univwesuty of Pretoria. Available at: http://upetd.up.ac.za/thesis/available/etd-07252012-132647/unrestricted/dissertation.pdf.

Rahman, A. S., Khandoker, M., Husain, S., Apu, A., Mondal, A.. and Notter, D. (2008). Morphometric Characterization And Relationship Of Body Weight With Linear Body Measurements In Black Bengal Buck. *Bangladesh Journal of Animal Science* 37(2):8–16.

Rege, J. E. O. (1994). Indigenous African small ruminants: a case for characterization and improvement. In Small Ruminant Research and Development in Africa, *Proceedings of the Second Biennial Conference of the African Small Ruminant Research Network* (pp. 205-211).

Rege, J. E. O. and Lipner, M. E. (1992). African Animal Gnetic Resources: their Characterisation, Conservation and Utilisation. In; *Proceedings of the Researh Planning Workshop, ILCA.* 19th -21st February 1992. Addis Ababa, Ethiopia.

Rege, J. E. O. and Okeyo M. A. (2006). Improving our knowledge of tropical indigenous animal genetic resources *In*: Animal Genetics Training Resource, version 3, 2011. Ojango, J.M., Malmfors, B. and Okeyo, A.M. (Eds). International Livestock Research Institute, Nairobi, Kenya and Swedish Universityof Agriultural Sciences, Uppsala, Sweden. Available at: https://hdl.handle.net/10568/3663 (Accessed: 5 March 2020).

Ryder, M. L. (1984). Sheep. In: Mason, I.L. (ed.) Evolution of Domestic Animals. Longman, London.85p

Sölkner, J., Nakimbugwe, H. and Valle, Z. (1998). Analysis of determinants for success and failure of village breeding programmes. *Proceedings of the Sixth World Congress on Genetics Applied to Livestock Production,* pp. 273–280. Bonn, Germany.

Statistics Botswana, (2016). Agricultural census stats brief of 2015. Gaborone, Botswana http://www.statsbots.org.bw/sites/default/files/Botswana Agriculture Census Report Final 2015..pdf

Tavirimirwa, B., Mwembe, R., Ngulube, B., Banana, N. Y. D., Nyamushamba, G. B., Ncube, S. and Nkomboni, D. (2013). Communal cattle production in Zimbabwe: *A. Development,* 25,12.

Taye, M., Bimerow, T., Yitayew, A., Mekuriaw, S. and Mekuriaw, G. (2012). Estimation of Live Body Weight From Linear Body Measurements for Farta Estimation of Live Body Weight From Linear Body. *Online Journal of Animal and Feed Research* 2(1):98–103.

Woolliams, J. A., Matika, O. and Pattison, J. (2008). Conservation of animal genetic resources: approaches and technologies for in situ and ex situ conservation. *Animal Genetic Resources Information* 42:71–85.

Yakubu, A. and Ibrahim, I. A. (2011). Multivariate analysis of morphostructural characteristics in Nigerian indigenous sheep. *Italian Journal of Animal Science*. 10(2):83–86.

Zeder, M. A. (2008). Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact. *Proceedings of the National Academy of Sciences of the United States of America*, 105(33) :11597–11604.

Zewdu, E. (2008). Characterization of Bonga and Horro indigenous sheep breeds of smallholders for designing community based breeding strategies in Ethiopia. MSc thesis submitted to the department of animal science, school of graduate studies, Haramaya University .33p.

CHAPTER 3

Production characteristics and management practices of Indigenous Tswana Sheep in Southern districts of Botswana

3.1. Abstract

Understanding the production environment and breeding practices practiced by indigenous Tswana sheep farmers is important in designing successful breeding programs. The aim of this study was to characterize indigenous Tswana sheep production systems, investigate their management and assess the farmers preferred selection traits when selecting breeding rams in four Southern districts of Botswana. 105 households from four districts of Southern Botswana; Kgatleng (n=30), Kweneng (n=27), Southern (n=24) and South-East (n=24) were interviewed using structured questionnaire. An index-based approach was used to rank farmers' choices of traits considered important for their production systems. Statistical Package for Social Sciences were used to analyze the data and Chi-square test (X^2) was used to assess the statistical significance among categorical variables. The demographic results indicates that indigenous Tswana sheep are mainly kept by males, single people, aged between range of 51-60 people and possessing primary and secondary level of education. The major source of income for Kweneng and Southern district farmers was livestock (index= 0.513 and 0.501, respectively) while for Kgatleng and South-East districts was wages/salaries (0.546 and 0.570, respectively). Superior fitness traits of indigenous Tswana rams over exotic rams was considered more important in selecting breeding rams in Kgatleng (0.290), Kweneng (0.301) and South-East (0.247) while in Southern district rams were mainly selected based on body size (0.372). More farmers (81.9%) kept rams for breeding purposes whilst 18.1% did not keep rams and depended on communal rams for service. Other management practices across the districts include castration, health care using veterinary services, communal

grazing and supplementation mostly during the dry season. The information obtained in the study will be useful in designing breed improvement and conservation programmes and inform sustainable utilization of indigenous Tswana sheep genetic resources in Botswana.

Key words: Breeding practices, Husbandry, Traits preferences, Tswana sheep

3.2. Introduction

Sheep play an important role in the socio-economic lives of people around the world including in Botswana (Nsoso *et al*., 2004b). They are kept for their economic, scientific and sociocultural value (Mavule *et al*., 2013; Aganga and Aganga, 2015) to mankind as well as agricultural productivity for the present and posterity (Gibson *et al*., 2006). They provide their owners with a wide variety of products and services such as meat, milk and immediate cash income (Baleseng *et al*., 2016). Compared to large ruminants such as cattle, sheep are highly prolific, have shorter generation interval and generally require low capital investment (Gizaw *et al*., 2008). In addition, sheep require small space and feed hence ideal to be kept by resource poor smallholders especially in areas where there is minimal grazing land.

In Botswana there are about 300 000 sheep of various breeds of which 65% are indigenous Tswana sheep (Statistics Botswana, 2016). The indigenous Tswana sheep dominates the national flock population because of its high adaptation to prevalent harsh environmental conditions and resilience to endemic diseases. They can walk long distances and survive well on low quality forages (Nsoso *et al*., 2004b). Under such environmental conditions, the performance of Tswana sheep with regards to survival and production is better than its exotic counterparts such as Dorper (Government of Botswana, 2011). Despite all these, the existence of Tswana sheep is under threat of immensely being replaced by the less adapted exotic breeds and crossbreds (Statistics Botswana, 2016) that are of high maintenance costs to resource poor rural farmers. This is because farmers practice uncontrolled crossbreeding that is done without evaluating and setting optimum breeding goals (Van Marle-Koster *et al*., 2015).

There is need to develop realistic breed improvement programs that will ensure sustainable utilization of local animal genetic resources (AnGR). The prerequisite to achieve this, is to firstly understand their existing natural production environment and the current context of their utilization. This includes indigenous knowledge on selection, management and identification of breeding goals (Kogsey *et al*., 2006). In Botswana, previous studies that described the production systems of indigenous Tswana sheep are not only scarce but limited in their scope to provide an in depth analysis of the sheep production systems. The aim of this study was therefore to characterize existing indigenous Tswana sheep production systems, investigate the management practices practiced by rural farmers keeping indigenous Tswana sheep and establish farmers preferred traits in selection of breeding rams in the Southern part of Botswana. This information will be useful in guiding policy makers in devising strategies to improve productivity and sustainable utilization of Tswana sheep and inform conservation programmes of the breed.

3.3. Materials and Methods

3.3.1. Study sites

A survey was conducted in Kgatleng (24°15'S 26°30’E), Kweneng (24°00'S 25°00'E) South East (25°00'S 25°45'E) and Southern (25°00'S 25°00'E) districts of Botswana (Figure 3.1) from November 2020 to January 2021. The climate is mainly semi-arid with high temperatures occurring from October to April and low temperatures occurring from around May to August. Rainfall is low, unreliable, not evenly distributed and highly variable from year to year. The vegetation type in all districts is savannah with tall grasses, bushes and trees (Woods and Sekhwela, 2012).

3.3.2. Sampling procedure

A multi-stage purposive sampling technique was employed for selection of districts for the study. In the first stage, discussions were held with district agricultural experts of the Department of veterinary services to know the distribution of indigenous Tswana sheep population in each district in Botswana. Based on the distribution, four districts (Kgatleng, Kweneng, South-East and Southern) were selected for the survey study. Random sampling was then used to select representative villages within districts and households/farms within villages. In each randomly selected village, four to five households were randomly selected for the survey study. Individual farm/household visits were made by the team which comprised extension area veterinary workers and researchers who briefed households about the objectives of the study and administered the questionnaire after consent was given.

3.3.3. Data collection

A structured questionnaire and visual observations were used to investigate and collect information on the production and management systems applied to indigenous Tswana sheep from a total of 105 households in the four districts of Southern Botswana namely; Kgatleng (n=30), Kweneng (n=27), Southern (n=24) and South-East (n=24). The questionnaire was a slightly modified version of those designed and recommended for livestock breed surveys in Africa (Bath *et al*., 2016; Hirwa *et al*., 2017). The questionnaire included socio-economic parameters (demographic) (e.g. gender, age, marital status and education level of indigenous Tswana sheep farmers), breeding management and methods of watering sheep, feeds and feeding management of the sheep, selection criteria and major production systems of each respondent in each district. Participants were asked to rank their major sources of income, to describe their ram selection criteria (ranging from1 to 3, where 1=most important and 3=least important).

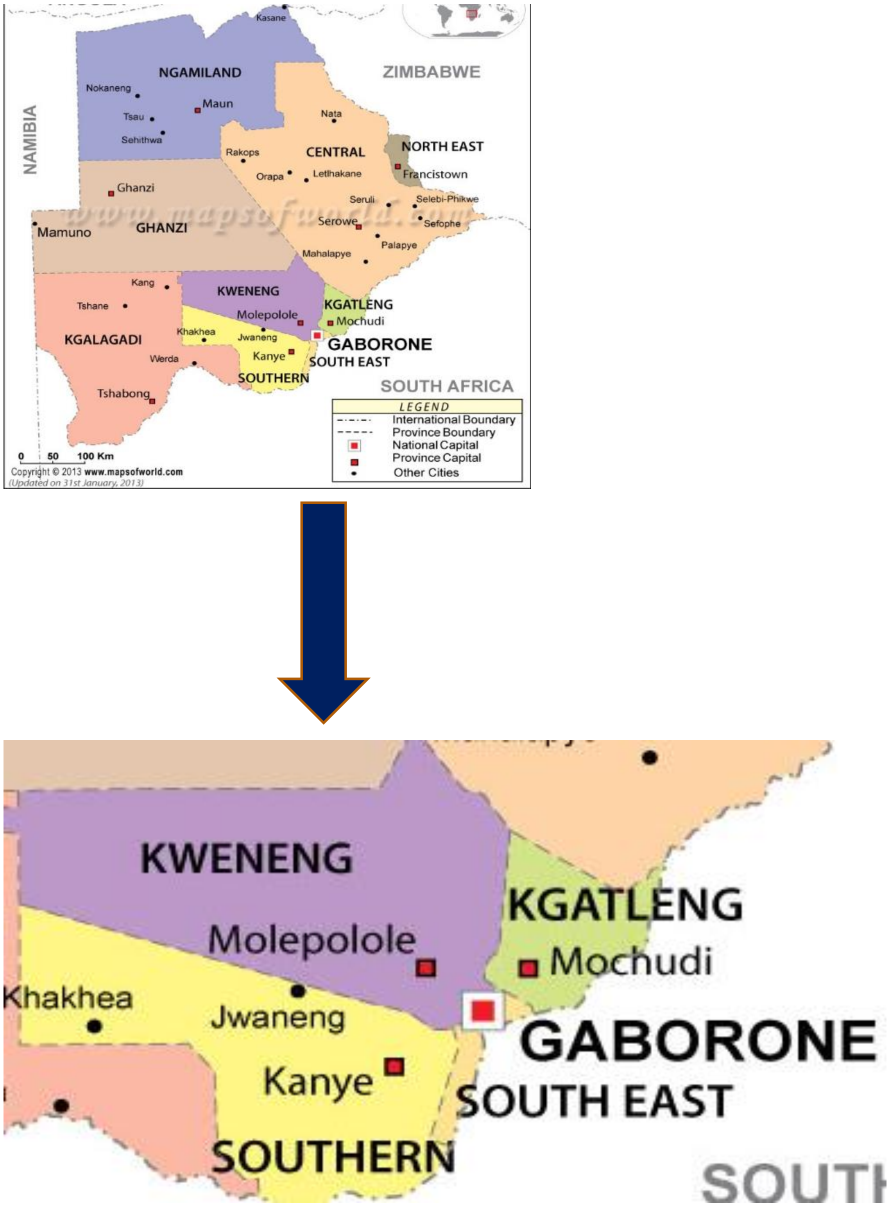

Figure 3.1 Map of the geographical location of study areas in Southern Botswana

3.3.4. Index based ranking

Individual farmers ranked their criteria for preferred traits in ram selection and a weighted ranking approach was adopted to determine the relative importance of each criterion to a household. This approach was used for ranking major sources of income, reasons for keeping sheep and criterion used in selection of rams. The formulas by Kogsey (2004) and Tam and Le (2006) were adopted for the weighted criteria as follows:

$$\textbf{Relative importance index} = \frac{\Sigma w}{AN} = \frac{3n_3+2n_2+1n_1}{3N}$$

Where *w* is the weighting given to each factor by the respondent, ranging from 1 to 3. For example: n_1 = number of respondents for least important, n_2 = number of respondents for fairly important and n_3 = number of respondents for most important. *A* is the highest weight (i.e. 3 in this study) *N* is the total number of respondents. The relative importance index ranges from 0 to 1 (Kogsey, 2004; Tam and Le (2006).

3.3.5. Data analysis

The data from the questionnaires were coded, entered and analyzed using the Statistical Package for Social Sciences (SPSS, 2007). The descriptive statistics, frequency and cross tabulation procedures were used to analyze the data. Chi-square test (X^2) was used to assess the statistical significance at $P \leq 0.05$ level of significance.

3.4. Results and Discussion

The proportion of male headed households was higher than the proportion of female headed households (77.78% versus 22.22%). A large proportion of respondents (41.9%) were aged between 51 to 60 years (Table 3.1). There was generally a low participation of youth in sheep production observed in this study. Low participation of youth in sheep production observed in this study is consistent with several studies that reported low participation of Botswana youth in cattle (Nsoso and Rabasima 2004), chickens (Modise, 2004) and goat production (Monau *et al*., 2017). This might be because youth do not see agriculture as a viable sector of employment (FAO, 2012) and youth could be discouraged by associated constraints such as lack of land, water, regulatory policies and financial support. This is worrisome as youth should be drivers of the country's livestock industry for sustainable development and growth of different livestock sectors. According to Monau *et al.,* (2017) most young people are more learned and equipped with agricultural skills thus it would be much easier for them to easily adopt modern farming technologies for enhanced agricultural production which would alleviate poverty and improve livelihoods in the rural populace.

A higher proportion of respondents from Kgatleng (67.7%) and South-East (54.2%) were not married while an equal proportion of married to unmarried respondents were observed in Kweneng (51.9%:48.1%) and Southern (50%:50%) districts. The results are comparable to the findings of Nsoso *et al*., (2004b) on survey on small ruminants in Kweneng districts of Botswana. A high proportion of head of households in Kgatleng (40.0%), Kweneng (40.7%) and South-East (54.2%) attained primary education and 62.5% of Southern district heads of households attained secondary education. More farmers in Kgatleng, Kweneng and South-East districts with primary education is consistent with Zewdu (2008) who reported that most sheep farmers from Adiyo kaka (70.2%) and Horro (48.7%) regions of Ethiopia attained primary school level of education. The literacy level of the farmers provides them with an opportunity to devise informed interventions in response to evolving production systems and enhance their management ability of the animals (Kogsey *et al*., 2006).

Respondents in all regions were small-scale communal farmers practicing mixed crop-livestock farming. The livelihood of most farmers (79%) was based on livestock production and those farmers raised their sheep under extensive production system in communal areas. Only 21% of the respondents depended on ploughing as the major activity compared to livestock production.

Table 3.1 Demographic and Socio-economic characteristics of the households keeping sheep in the four districts of Southern Botswana

Descriptors	Kgatleng (%)	Kweneng (%)	Southern (%)	South-East (%)	Overall total (%)	X^2 P Value
Gender						
Male	83.3	77.8	83.3	66.7	77.78	
Female	16.7	22.2	16.7	33.3	22.22	0.44
Age (years)						
≤ 30 years	3.3	0	0	0	0.83	
31-40	16.7	0	25.0	16.7		
41-50	20.0	29.6	20.8	20.8		
51-60	43.3	40.7	33.3	50.0		0.35
61-70	13.3	18.5	20.8	12.5		
>70	3.3	3	0	0		
Not known	0	0	0	0		
Marital status						
Married	33.3	51.9	50	45.8		
Single	67.7	48.1	50	54.2		0.42
Level of Education						
None	0	3.7	12.5	0		
Primary	40.0	40.7	16.7	54.2		0.01
Secondary	36.7	37.0	62.5	12.5		
Tertiary	23.3	18.5	8.3	33.3		
Is Livestock major activity						
Yes	93.3	96.3	62.5	58.3	79	0.01
No	6.7	3.7	37.5	41.7	21	
Type of production system						
Intensive/industrial	0	0	4.2	0		
Extensive/pastoral	86.7	96.3	91.7	75.0		0.10
Semi intensive	13.3	3.7	4.2	25.0		

3.4.1. Livestock holding per household and flock structure

Most of livestock species kept in the districts include cattle, sheep, goats, poultry, donkeys and pigs. There were no significant differences in the number of sheep per household across the four districts although the Southern district had more sheep per household (30.08±3.77) (Table 3.2). Similar average number of sheep per household across the districts attest to the increasing popularity and importance attached to sheep across the country. Respondents in the current study preferred keeping sheep than cattle because they are resilient to diseases commonly found in the Southern region and can survive on marginal feeds sourced along farm boundary, along streams/rivers and roadsides compared to cattle. Similar reasons for preference of sheep over cattle has been reported by Deribe (2009) for Alaba Special Woreda farmers of Southern Ethiopia. It was also noticed that though the South-East district is well known for pig production (Nsoso *et al*., 2005), farmers keeping Tswana sheep in the district kept a very low number of pigs. They reported that pigs infected sheep with sheep scab disease especially during dry seasons.

Table 3.2 Average number of livestock species per household in the four surveyed districts of Southern Botswana

Species	**Kgatleng Mean±SE**	**Kweneng Mean±SE**	**Southern Mean±SE**	**South-East Mean±SE**
Sheep	22.20±3.8	24.81±3.56	30.08±3.77	23.58±3.77
Goats	25.633±5.0	32.56±5.25	35.54±5.57	24.29±5.57
Cattle	13.03 ± 2.84^{ab}	17.96 ± 2.99^{a}	5.75 ± 3.17^{bc}	4.04 ± 3.17^{c}
Chicken	11.20 ± 1.79^{a}	8.74 ± 1.89^{a}	2.75 ± 2.00^{b}	9.42 ± 2.00^{a}
Donkeys	2.23 ± 0.43^{ab}	2.23 ± 0.46^{a}	0.17 ± 0.48^{bc}	0.96 ± 0.48^{c}
Pigs	0.27±0.13	0.15±0.15	0.13±0.15	0.04±0.15

^{a,b,c} Means across rows with different superscripts were significantly different at (P<0.05)

3.4.2. Purpose of keeping sheep

Understanding the purposes for which farmers keep sheep is important in formulating breeding goals in the tropics Kogsey *et al*., (2008) and should not be ignored if breed improvement and conservation programmes are to be drawn. The multifaceted roles played by sheep in the livelihoods of farmers identified in this study (Table 3.3) are a direct reflection of the farmers multiple objectives for sheep production. The primary purpose of keeping sheep in Kgatleng and

Kweneng districts is for cash derived from selling the animals (index= 0.480 and 0.390, respectively) followed by investment (index= 0.231 and 0.221, respectively) and meat consumption (index= 0.211 and 0.210, respectively). Southern and South-East district farmers primarily kept sheep for ceremonies (socio-cultural) (index=0.310 and 0.371, respectively) followed by cash sales and meat consumption. The preference of sheep in generating household income via sales reported in Kgatleng and Kweneng districts is consistent with Kogsey *et al*., (2008) who outlined the importance of livestock in generating income for small ruminant farmers in Kenya amongst other purposes. The Southern and South-East districts prioritized non tangible benefits for keeping sheep like ceremonial value over generation of income. According to farmers in the South-East and Southern districts, the esteemed preference and use of sheep in ceremonies particularly weddings is symbolic in that sheep are considered naturally noble animals which brides should emulate in their behavior towards their in-laws. Other outstanding purposes for keeping sheep included rearing sheep as an investment and as a source of meat. Purposes like use of sheep for dowry payment and cultural rites received relatively low ranking among the reasons for keeping sheep in all the districts under study. These findings are in consonance with the report of Edea *et al*., (2012) who reported similar multi-purpose functions of sheep rearing in Western and South-Western Ethiopia. The importance of multiple values of indigenous livestock breeds in developing countries in low input system have been addressed in different studies; Kosgey (2004); Mwacharo and Drucker, (2005); Wurzinger *et al*., (2006) ; Zewdu *et al*., (2006).

The major source of income for Kweneng (0.513) and Southern (0.501) districts farmers was livestock and livestock products whilst wages/salaries was the major source of income for Kgatleng (0.546) and South-East (0.570) farmers. The high dependency of Kgatleng and South-East farmers on wages and salaries as a major source of income observed in this study was attributed to their proximity to urban or peri-urban areas where they have other means of cash flow income other than agriculture. Furthermore, majority of farmers in these districts are well educated and therefore have formal employment hence wages/salaries as their main source of income. A similar observation was made by Monau *et al*., (2017) who reported that indigenous Tswana goat farmers in the Southern region of Botswana preferred piece jobs as a major source of income over livestock sales and that was attributed to their proximity to urban or peri-urban areas.

Table 3.3 Indices and their ranking for reasons for keeping sheep and source of income by respondents in surveyed districts of Botswana.

Descriptors	Kgatleng index	Rank	Kweneng index	Rank	Southern index	Rank	South-East index	Rank	χ^2
Purpose of keeping sheep									
Meat	0.211	3	0.210	3	0.180	4	0.160	4	0.01
Investment	0.231	2	0.221	2	0.211	3	0.250	2	
Ceremonies	0.030	4	0.171	4	0.310	1	0.371	1	
Cash	0.480	1	0.390	1	0.231	2	0.201	3	
Dowry payment	0.031	4	0.000	5	0.000	5	0.000	5	
Cultural rites	0.020	5	0.000	5	0.000	5	0.000	5	
Source of income									
Crop production	0.130	3	0.208	3	0.300	2	0.191	3	
Livestock and products	0.324	2	0.513	1	0.501	1	0.230	2	
Wages/salaries	0.546	1	0.279	2	0.181	3	0.570	1	0.11

3.4.3. Labor profile in sheep husbandry and Decision Making

The detailed roles of householder members responsible for sheep husbandry activities in Kgatleng, Kweneng, Southern and South-East districts are presented in Table 3.4, 3.5, 3.6 and 3.7, respectively. Sheep management activities were carried out mainly by family members and the involvement of individuals outside the family was less across the study districts. Most of the activities related to both purchasing and selling were mainly done by males aged above 15 years (80% for Kgatleng, 92.6% for Kweneng, 87.5% for Southern and 75% for South-East). Similarly, breeding activities (83.3% for Kgatleng, 88.9% for Kweneng, 87.5% for Southern and 75% for South-East) and slaughtering (43.3% for Kgatleng, 85.2% for Kweneng, 70.8% for Southern and 45.8% for South-East) were mainly performed by males aged above 15 years of age, precisely by head of household who were also the owners of the sheep. These findings are similar to the report of Zewdu (2008) for Horro and Adiyo Kaka districts in Ethiopia and Verbeek *et al*., (2007) who reported that breeding decisions were made by male members of the households in Kenya. This characteristic of the production system is consistent with Nsoso *et al*., (2004b) and Abegaz (2007) who reported that this production system is characterized by, among others informal labor derived from family members. This could be because sourcing labor from family members is less costly to the resource poor families compared to hiring labor. This practice is also a way to train and teach children livestock keeping practices for posterity.

Table 3.4 Household members responsible for routine sheep husbandry practices in Kgatleng district (%)

Responsible bodies	Activity					
	Purchasing	Selling	Herding	Breeding	Sick animals care	Slaughtering
Males≥ 15 years	80	80	40	83.3	26.7	43.3
Females≥15 years	16.7	16.7	10	16.7	3.3	6.7
Males< 15 years	-	-	6.7	-	-	6.7
Males< 15 years	-	-		-	-	-
Hired labor	-	-	43.3	-	20	43.3
Males≥ 15 years and hired labor	3.3	3.3	-	-	40	-
Females≥ 15 years and hired labor	-	-	-	-	10	-

Across districts, hired labor and children (males and females under 15 years of age) hardly participate in purchasing, selling or breeding decisions. However, hired labor mostly participated in herding (43.3% for Kgatleng, 25.9% for Kweneng, 25% for Southern and 29.2% for South-East) and slaughtering of sheep (43.3% for Kgatleng, 14.2% for Kweneng, 16.7% for Southern and 54.2% for South-East) especially in households led by women or elderly people who do not have strength to herd, administer medication to sick animals or slaughter animals for themselves.

Table 3.5 Household members responsible for routine sheep husbandry practices in Kweneng district (%)

Responsible bodies	Activity					
	Purchasing	Selling	Herding	Breeding	Sick animals Care	Slaughtering
Males≥ 15 years	92.6	92.6	70.4	88.9	63	85.2
Females≥15 years	7.4	7.4	3.7	7.4	3.7	-
Males< 15 years	-	-	-	-	-	-
Males< 15 years	-	-		-	-	-
Hired labor	-	-	25.9	3.7	11.1	14.2
Males≥ 15 years and hired labor	-	-	-	-	18.5	-
Females≥ 15 years and hired labor	-	-	-	-	3.7	-

Table 3.6 Household members responsible for routine sheep husbandry practices in Southern district (%)

Responsible bodies	Activity					
	Purchasing	Selling	Herding	Breeding	Sick animals care	Slaughtering
Males≥ 15 years	87.5	87.5	58.3	87.5	75.0	70.8
Females≥15 years	12.5	8.3	8.3	12.5	8.3	8.3
Males< 15 years	-	-	8.3	-	-	-
Females< 15 years	-	-	-	-	-	4.2
Hired labor	-	4.2	25	-	12.5	16.7
Males≥ 15 years and hired labor	-	-	-	-	4.2	-
Females≥ 15 years and hired labor	-	-	-	-	-	-

The involvement of women in sheep husbandry activities was noticed mostly on households in which women were the heads of households and stayed alone or with herdsmen only. Although it is common practice that herding of small ruminants is done by children below 15 years as reported by Zewdu (2008) for Horro and Adiyo Kaka districts in Ethiopia and Verbeek *et al*., (2007) for small holder farmers in Kenya, this was not the case in this current study. The proportion of children involved in sheep husbandry activities was very minimal because the study was conducted during a time when schools were open, and children were at school.

Table 3.7 Household members responsible for routine sheep husbandry practices in South-East district (%)

Responsible bodies	Activity					
	Purchasing	Selling	Herding	Breeding	Sick animals care	Slaughtering
Males≥ 15 years	75	75	54.2	75.0	75	45.8
Females≥15 years	25	25	16.7	25	16.7	-
Males< 15 years	-	-	-	-	-	-
Males< 15 years	-	-		-	-	-
Hired labor	-	-	29.2	-	8.3	54.2
Males≥ 15 years and hired labor	-	-	-	-	-	-
Females≥ 15 years and hired labor	-	-	-	-	-	-

3.4.4. Breeding Management

Majority of farmers across districts (98.1%) practiced uncontrolled mating whilst only 1.9% controlled mating (Table 3.8). The observed uncontrolled mating across districts was associated with high dependency of farmers on grazing in unfenced communal grazing lands. Zewdu (2008) also reported a similar practice for Adiyo kaka and Horro sheep in Ethiopia. More farmers (81.9%) kept rams for breeding purposes whilst 18.1% did not keep rams and depended on communal rams for service. Farmers in Kgatleng (46.7%), Kweneng (77.8%) and Southern districts (75%) bred with their own rams originating from their own flock. South-East farmers (33%) predominantly used donated rams. Since most farmers owned their own breeding rams, it may imply that animals within a flock are closely related thus chances of inbreeding are high. Low entry of males in to the flocks either through purchase or other means may further escalate the inbreeding levels especially in small-sized flocks (Zewdu, 2008). When breeding rams were not reared in farmer's flocks, a considerable amount of farmers got the service from communal rams. This observation is in line with Zewdu (2008) who reported that majority of farmers who did not own rams got the service from their neighbors for Adiyo kaka and Horro sheep in Ethiopia. This practice could be a way to minimize the deleterious effects of inbreeding especially when coupled with other practices such as castration of males at an early age and rotational use of breeding males.

The high preference of own-bred Tswana males for breeding observed in Kgatleng, Kweneng and Southern districts might be because farmers consider indigenous rams to have better survival and reproductive performance than exotic breeds under Botswana production environment. A paradigm shift in farmers breeding goals towards generating income through animal sales was observed across districts but was more evident in the South-East as more farmers are beginning to prefer crossbred genotypes in mating. The Tswana breed rams were the main breeding rams used in Kgatleng, Kweneng and Southern districts whilst South-East district farmers preferred the Tswana and exotic crossbred genotypes (33%) and a combination of Tswana rams alongside crossbreds (29.2%). This might be because farmer's breeding goals in this area are more focused on few economically important traits of high market value like increased meat proportion using exotic genotypes and their crosses. Farmers in this district practice unplanned crossbreeding using Tswana-exotic crossbred rams in pursuit of taking advantage of breed complementarity (Van Marle-Koster *et al*., 2015) and heterosis effects (Zobell *et al*., 2019). This is done to meet the urban market demand for mutton in the capital city of Gaborone which is proximate to the districts. Ultimately, this will increase income but unfortunately might lead to the subsequent replacement of locally adapted breeds by the high-yielding international or trans-boundary breeds.

Table 3.8 Frequency of mating systems, source of breeding rams and breeds of rams in the four surveyed districts.

Descriptors	Kgatleng (%)	Kweneng (%)	Southern (%)	South-East (%)	Overall (%)	χ^2
Mating						
Uncontrolled	93.3	100	100	100	98.1	
Controlled	6.7	0	0	0	1.9	0.165
Source of breeding ram						
Own ram (self-bred)	46.7	77.8	75	12.5	53	0.001
Own ram (bought)	10	0	0	16.7	6.68	
Donated ram	6.7	0	12.5	33.3	13.13	
Communal area ram	23.3	11.1	12.5	16.7	15.9	
Own ram (self-bred) and own ram (bought)	13.3	7.4	0	20.8	10.38	
Borrowed ram	0	3.7	0	0	0.9	
Breed of ram						
Indigenous Tswana	26.7	44.4	58.3	16.7	36.5	0.004
Pure exotic (Dorper)	10	11.1	4.2	0	6.3	
Indigenous x exotic cross	23.3	14.8	12.5	33.3	20.98	
Tswana and Dorper	3.3	0	0	0	0.8	
Tswana, Dorper and cross	3.3	0	0	0	0.8	
Tswana and cross	3.3	0	4.2	29.2	9.2	
Dorper and cross	6.7	0	8.3	0	3.75	
Tswana, cross and beef master	0	0	0	4.2	1.05	
No ram	23.3	11.1	12.5	16.7	15.9	

3.4.5. Farmers preferred trait ranking

Selection of parents of the next generation is predominantly done in rams and all mature females are usually allowed to parent the subsequent generation. The use of preferences based on indices is a powerful tool for farmers to objectively and accurately rank their animals (Onzima *et al.*, 2018). The outcomes of the trait preferences by farmers when selecting breeding rams is presented in Table 3.9. Adaptation traits (disease tolerance/resistance, drought tolerance) summed up as superiority in competitive performance of Tswana sheep over its exotic counterparts under tropical conditions was considered the most important trait in Kgatleng (0.290), Kweneng (0.301) and South-East (0.247), followed by body size Kgatleng (0.251), Kweneng (0.262) and South-East (0.244). This might be because despite random mating taking place, theoretically farmers in the aforementioned districts consider and prefer indigenous rams to have better performance than exotic breeds in terms of survival and reproduction under the Botswana production environment. This is consistent with the report of Government of Botswana (2011).

The present study recognizes that adaptation traits are equally or more important than production traits to these farmers. Although highly adapted animals were desired, farmers also underscored the need for income from sale of animals hence a substantial proportion of farmers also ranked body size as a valuable trait of economic importance for them. Therefore, generally most farmers in the Southern district selected rams primarily on the basis of body size (0.372) followed by body conformation (0.311). The preference of production traits (body size) by Southern district farmers is attributed to their primary purpose for keeping sheep (ceremonial purposes where large bodied animals are preferred) hence the need for well grown, structurally sound and large-bodied animals. The desire for larger animals that can catch a better selling price/income has also been reported for farmers in Kenya (Zonabend König *et al*., 2015). Traits like availability (no choice) had the lowest indices across the districts as they were reported by only those farmers that benefited from government poverty alleviation programs such as Livestock Management and Infrastructure Development (LIMID) where rams were donated to them.

Table 3.9 Ranking of selection criteria of ram as reported by households (%) in the four surveyed districts of Southern Botswana.

Characteristic	Kgatleng index	Rank	Kweneng index	Rank	Southern index	Rank	South-East index	Rank	χ^2
Body size	0.250	2	0.262	2	0.372	1	0.244	2	
Body conformation	0.147	4	0.212	3	0.311	2	0.198	4	
Temperament	0.170	3	0.189	4	0.207	3	0.213	3	
Performance	0.290	1	0.300	1	0.068	4	0.247	1	0.04
Availability	0.083	5	0.037	5	0.042	5	0.071	5	

3.4.6. Castration practice

The reason for castration reported by most farmers across the four districts (99%) was primarily to control breeding (77.1%) followed distantly by temperament improvement plus controlling breeding (14.3%) and to a lesser extend controlling breeding plus to improve meat quality (7.6%). Similar reasons for castration have been in literature for Ethiopian sheep breeds (Taye *et al*., 2016; Getachew *et al*., 2010). Although it is commonly recommended that castration should be done at an earlier age in weeks, farmers in the study generally castrated their rams at a later age of more than 3 months especially Southern district farmers. Farmers in the Kgatleng (50%), Kweneng (48.1%) and South-East (58.1%) districts castrate their rams at 3-6 months of age whilst Southern district (50%) castrate their rams at 6-12 months. This finding is consistent with the report of Zewdu (2008) who reported an average castration age of 10.8 ± 2.5 months in Adiyo Kaka rams of Ethiopia and Taye *et al*., (2016) who reported an average castration age of 12.09±4.10 months in Doyogena rams in Ethiopia. This is because some sheep producers believe that castration at an early age 'stunts growth'. Entire males produce hormones that enhance faster growth rate than castrates, therefore castrating at 6-12 months of age gives the farmer some of the benefit of the increased male hormone growth effect before the animals are castrated. This is supported by the trials of Hybu (2004) who reported that carcasses of entire male lambs were up to 1kg heavier than those of castrates of the same age and they also had a lower fat content and thus improved meat quality.

3.4.7. Housing of sheep

All the farmers in all the districts under study house their sheep especially at night to prevent them from predators, thieves and harsh weather conditions and the sheep are kept in kraals both during the wet and dry seasons. This practice has also been reported by Taye *et al*., (2016) on Doyogena sheep of Ethiopia. 43.3% of Kgatleng farmers constructed their kraals with untreated wood/bush and wire while most of Kweneng and Southern farmers used untreated wood/bush, iron sheets and wire (Figure 3.2). 41.7% of South-East farmers mostly used treated wood, iron sheets and wire in constructing kraals for their sheep. The iron sheets provide covering during extreme adverse weather conditions such as heavy storms and sometimes hail which could otherwise kill sheep especially lambs.

Most farmers across districts, Kweneng (66.7%), South-East (58.3%) and Southern (50%) provided roof in their earth floored sheep kraals whilst most farmers in Kgatleng district (76.7%) did not provide roofing on their earth floored sheep kraals. However, earth floor kraals are usually piled up with manure and could easily become unhygienic and a favorable breeding ground for disease causing pathogens. Diseases such as foot rot, navel ill and other infectious diseases are inevitable in earth floors especially where there is inadequate surface drainage and confinement. This is confirmed by Lemma (2002) who reported that poor housing encourages diseases and other complexities because of overcrowding in traditional production systems. The earth floor also does not promote firm footing which may lead to animals slipping thus risking physical injury. Despite high disease tolerance, veterinary management remains imperative to improve overall productivity and welfare. The South-East farmers equally had both roof and earth floor form of housing as well as earth floor housing without roof.

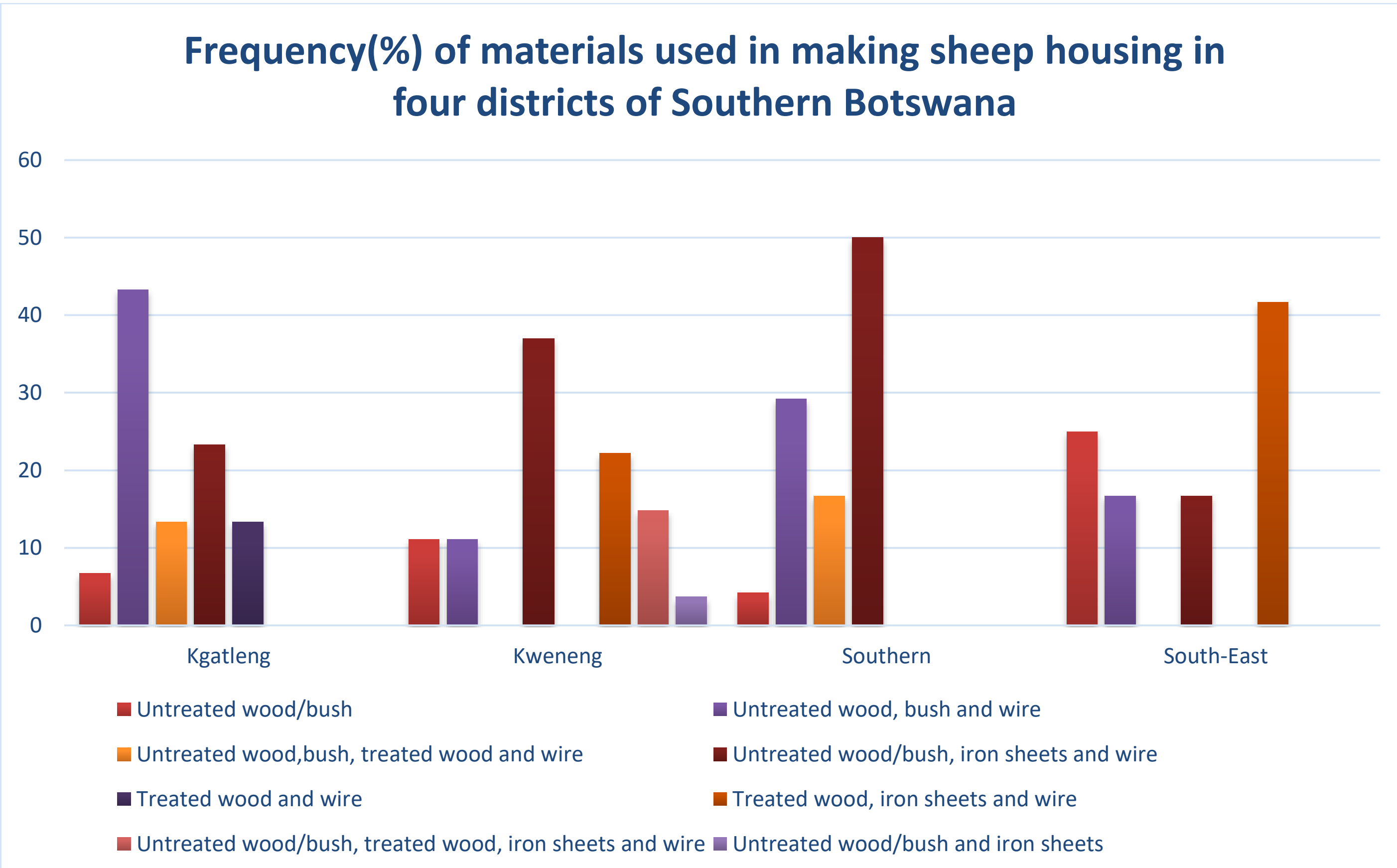

Figure 3.2 Types of materials used when constructing sheep housing structures in the surveyed districts of Southern Botswana

3.4.8. Feeding and supplementation

Inadequate feeding and poor-quality feed especially during the dry season are often regarded as major factors limiting sheep production (Kogsey *et al*., 2008). Most of the respondents across districts solely depended on freely grazing their sheep on natural pasture in communal grazing land as the major feed source during both the dry and wet seasons (Table 3.10). The dependency of farmers on communal areas to meet the nutritional requirements of their animals as revealed in the current study concurs with the findings of Belete (2009) and Mavule *et al*., (2013). In addition to natural pasture, some farmers across districts practiced supplementary feeding during both the dry and rainy seasons using a variety of feed resources including roughages/crop residues, mineral blocks and bought concentrates.

Overall, 53.3% of farmers across districts supplemented with roughage/crop residues during the dry season while a small fraction (12.9%) of farmers across districts supplemented with crop residues and bought in concentrates. This supplementary feeding is ascribed to unreliability and poor nutritive value of the scarce roughage especially during drought/dry periods. Supplementation with salt mineral licks and vitamins was not common across the study districts. The low proportion of farmers who use salts and vitamins as supplements for sheep in the current study is inconsistent with Zewdu (2008) for Horro and Adiyo Kaka sheep in Ethiopia and Solomon (2007) for Gumuz sheep in Ethiopia. Most farmers (overall of 64.8% across all districts) did not supplement during the wet season. Lack of supplementation during the wet season as reported in this study is attributed to abundance of natural pasture in both quantity and quality.

Furthermore, during the survey it was observed that as a general management practice, sheep were kept for longer hours in kraals during the wet season than the dry season. The late release of sheep for grazing during the wet season might be attributed to the fact that animals graze to their satiety in shorter grazing time due to pasture availability. A similar observation was reported by Mavule *et al*., (2013) for KwaZulu-Natal sheep in South-Africa. In further agreement to this observation, Zewdu (2008) reported that sheep in Adiyo Kaka in Ethiopia grazed for a shorter time (7.4 hours a day) during the wet season and grazed for a longer time (9.6 hours a day) during the dry season as a strategy to cope with feed shortage. The same management practice has also been reported by Legesse *et al*., (2008) for Adilo and Kofele sheep of Southern Ethiopia.

Table 3.10 Frequency (%) of supplementary regime used on sheep in the study areas during wet and dry seasons

Supplement	Kgatleng	Kweneng	Southern	South East	Overall	χ^2
Dry season						
Roughage/crop residue	46.7	66.7	50	50	53.3	0.12
Bought feed/concentrates	16.7	3.7	4.2	4.2	7.6	
None	26.7	3.7	12.5	20.8	16.2	
Roughage/crop residues and Mineral (Salts)/ Vitamins	3.3	7.4	16.7	-	6.8	
Roughage/crop residue and bought feed/concentrates	3.3	14.8	16.7	16.7	12.9	
Minerals (salts)/vitamins and bought in feed/ concentrates	3.3	3.7	-	8.3	3.8	
Wet season						
Roughage/crop residue	16.7	33.3	12.5	25	21.9	
Bought feed/concentrates	3.3	3.7	4.2	8.3	4.8	
None	76.7	55.6	66.7	58.3	64.8	0.08
Roughage/crop residues and Mineral (Salts)/ Vitamins	3.3	3.7	12.5	8.3	6.95	
Roughage/crop residue and bought feed/concentrates	-	3.7	4.2	-	1.98	
minerals (salts)/vitamins and bought in feed/ concentrates.	-	-	-	-	-	

3.4.9. Diseases and health management

Less or no disease load was reported across districts except occasional pasteurellosis. Parasitic diseases particularly heart water was reported in lesser incidences in Kweneng district especially after the rainy season. However, typical disease symptoms like coughing, sneezing, bloating and substantial mucus discharged from the nostrils were common across districts. The common symptom of mucus discharged from sheep nostrils was probably due to lack of vaccination against internal parasites, pasteurella and pulpy kidney. *Pasteurella multicoda,* one of pasteurellosis causing pathogens causes nasal discharge in sheep (Odugbo *et al*., 2006). Disease symptoms incidences and transmission were common as most sheep flocks freely roam and mix with each other at communal grazing areas and at shared drinking points. Similar findings have been previously reported by Debire (2009) for Alaba sheep of Ethiopia.

Most of the farmers had access and used modern medication and hardly used ethno-veterinary practices for disease control. The low proportion of farmers using ethno-veterinary services across districts could be because most of the farmers received formal education and may be less knowledgeable about ethno-veterinary practices hence resort to modernized herd health practices. These findings concur with Mavule *et al*., (2013) who reported that a few farmers in their study used traditional plants as supplements and for veterinary use. Contrary to the current study, Debire (2009) reported that 90% of participants in their study in Ethiopia used traditional medication and the remaining 10% used modern veterinary drugs.

The modes of accessing veterinary services cross districts are summarized in Figure 3.3. Farmers in the Kgatleng district (26.7%) and Kweneng district (29.6%) mainly got their veterinary services from the government during scheduled national herd health vaccination programs. Most South-East farmers depended on extension officers for veterinary services and half of farmers in the

Southern district attended their sheep themselves when they needed veterinary attention. The high proportion of Southern district farmers who provide health care for their own animals is associated with their literacy level. A higher literacy level provides farmers with an opportunity to devise informed disease combating interventions in response to disease outbreaks and enhance their management ability of the animals (Kogsey *et al*., 2006).

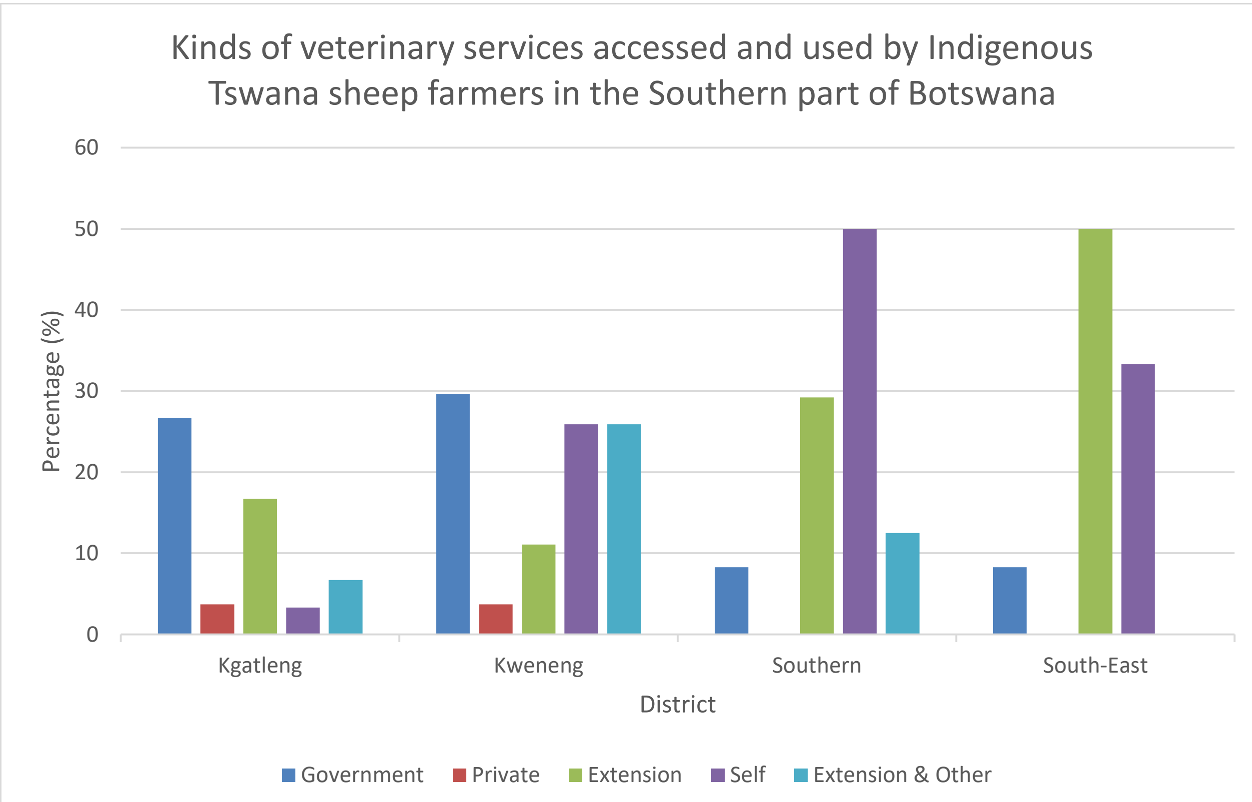

Figure 3.3 Kinds of veterinary services accessed and used by Indigenous Tswana sheep farmers in the four districts of Botswana.

3.4.10. Watering sheep

A proportion of farmers (49.3%) provided water for their sheep across the districts during the dry season while 61% of the respondents indicated that their animals go to the water source during the wet season. Specifically, most of the farmers in Kweneng (59.3%) and Southern (62.5%) districts reported that water is provided to the animals during the dry season while 53.3% of Kgatleng district farmers and 41.7% of South-East district farmers reported that their animals go to the water source during the dry season. Borehole was the major source of water during the dry season across districts and it accounted for 63.3%, 85.2%, 37.5% and 20.8% of the total water source during the dry season in Kgatleng, Kweneng, Southern and South-East districts, respectively. The water was reported to be good and clear. During the wet season, the dam/pond was the major source of water and it accounted for 50%, 62.5% and 20.8% of the total water source in Kgatleng, Southern and South-East respectively. This is not a surprise as rain water is readily available in dams and ponds during the rainy season, however, drinking dirty/muddy water from dams/ponds and rivers predisposes animals to diseases (Peacock, 2005). Kweneng district farmers (44%) reported borehole as the major source of water during the wet season. This is because most of the district is covered with loose sandy soils that are porous and so hold water for only short periods of time after the rains (Graham, 1995).

Municipal or piped water source was the least reported by all farmers during both the wet and dry seasons probably because the survey was carried out in the remote lands where there were no municipal pipes. A watering distance of less than 1 km was reported by majority of farmers during both the dry and wet seasons. This finding agrees with the findings of Zewdu (2008) for Adiyo Kaka and Horro farmers in Ethiopia. In agreement with Debire (2009) for Alaba sheep of Ethiopia, the short distance to the drinking point allowed sheep to have water *ad libitum* during both seasons as reported by most farmers in the current study.

3.5. Conclusion

Indigenous Tswana sheep are kept in mixed-crop-livestock system in the communal areas of the Southern part of Botswana. Sheep serve socio-economic and cultural values apart from providing meat, milk and non-profitable benefits like manure. Indigenous Tswana sheep are mainly kept by males, single people, aged between 51-60 and possessing primary and secondary level of education. Most farmers depend on free grazing as the major feed source with supplementary feeding practiced only during the dry season when feed quality and quantity is compromised. Performance, in terms of survival and reproductive ability, body size and conformation were the highly preferred traits in selecting rams. Farmers prefer keeping Tswana rams originating from their own flocks for breeding purposes and prefer castration of males to be done at a later stage of 6-12 months.

3.6. References

Abegaz, S.G. (2007). In situ characterization of Gumuz sheep under farmer's management in North Western lowland of Amhara region. M.Sc. Thesis, Alemaya University of Agriculture, Dire Dawa, Ethiopia.

Aganga, A. O. and Aganga, A. A. (2015). Quality Assurance in Goat Meat Production for Food Safety in Botswana. *Asian Journal of Biological Sciences* 8(2):51–56.

Baleseng, L., Kgosikoma, E. O and Makgekgenene, A. (2016). Perfomance of goats and sheep under communal grazing in Botswana using various growth measures. In *Proceedings of ICAS V11 Seventh International Conference on Agricultural Statistics*. 24^{th}-26^{th}. October 2016. Rome.

Bath, G. F., Penrith, M-L. and Leask, R. (2016). A questionnaire survey on diseases and problems affecting sheep and goats in communal farming regions of the Eastern Cape Province, South Africa. Journal of the South African Veterinary Association 87(1): 1-10.

Belete, S. (2009). Production and marketing systems of small ruminants in Goma district of Jimma zone, western Ethiopia. MSc. Thesis. Hawassa University, Hawassa, Ethiopia. pp. 35-82.

Deribe, G. (2009). On-Farm Performance Evaluation of Indigenous Sheep and Goats in Alaba, Southern Ethiopia. MSc Thesis presented to the School of Graduate Studies of Hawassa University, Hawassa, Ethiopia.

Edea, Z., Haile, A., Tibbo, M., Sharma, A., Sölkner, J. and Wurzinger, M. (2012). Sheep production systems and breeding practices of smallholders in western and south-western Ethiopia: Implications for designing community-based breeding strategies. Livestock Research for Rural Development. 24.

Food and Agriculture Organization (FAO), (2012). Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No.11. FAO, Rome, Italy.

Getachew, T., Haile, A., Tibbo, M., Sharma, A. K., Sölkner, J. and Wurzinger, M (2010). Herd Management and Breeding Practices of Sheep Owners in a Mixed Crop-livestock and a Pastoral System of Ethiopia. *African Journal of Agricultural Research* 5 (8):685-691.

Gibson, J., Gamage, S., Hanotte, O., Iñiguez, L., Maillard, J. C., Rischkowsky, B., Semambo, D., and Toll, J. (2006). Options and strategies for the conservation of farm animal genetic resources: Report of an International workshop. AGROPOLIS, (7–10 November 2005, Montpellier, France).

Gizaw, S., Komen, H., Hanote, O. and Van Arendonk, J. A. M. (2008). Indigenous sheep resources of Ethiopia: types, production systems and farmers preferences. *Animal Genetics Resources Information* 43:25-39.

Government of Botswana (2011). Small Stock Management Practices. Retrieved February 19, 2020, from https://.www.gov.bw/en/Ministries--Authorities/Ministries/ Ministry of Agriculture-Moa/Tools--Services/Livestok/Small -Stock-Management-Practices.

Graham, M. (1995). Environmental change at Letlhakeng in the Kweneng District. Botswana Notes and Records. (27). Pp. 281-298.

Hirwa, C. D., Donald, K., Murekezi, T., Jean, R., Aline, K., Arsene, M., Jean, S., Felicien, S., Manzi, M. and Theogene, S. (2017). Management and phenotypic features of indigenous cattle in Rwanda. International Journal of Livestock Production. 8(7): 95-112.

Hybu, C. C. (2004). Rearing entire males. Retrieved on 14 April 2021 from www.hccmpw.org.uk/medialibrary/pdf/EN_539_Rearing%20Entire%20Males.pdf

Kosgey, I. S. (2004). Breeding objectives and breeding strategies for small ruminants in the Tropics. Ph.D. Thesis, Wageningen University, The Netherlands. (ISBW: 90-5808-990-8) Germany. pp. 271

Kosgey, I. S., Baker, R. L., Udo, H. M. J. and Van Arendonk, J. A. M. (2006). Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research* 61(1):13-28.

Kogsey, I. S., Rowlands, G. J., van Arendonk, J. A. M. and Baker, R. L. (2008). Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research* 77:11-24.

Lemma, S. (2002). Phenotypic classification and description of indigenous sheep types in the Amhara National Regional State of Ethiopia. MSc thesis. University of Natal, Pietermaritzburg, South Africa.

Legesse, G., Abebe, G., Siegmund-Schultze, M and Valle-Zárate, A. (2008). Small ruminant production in two mixed-farming systems of southern Ethiopia: Status and prospects for improvement. *Experimental Agriculture*. 44(3):399-412.

Mavule, B. S., Muchenje, V. and Kunene, N. W. (2013). Characterisation of Zulu sheep production system: Implications for conservation and improvement. *Scentific Research Essays*. 8 (26):1226–1238.

Modise, O. M. (2004). A survey of indigenous Tswana chickens in selected areas of Kgatleng district in Botswana: Demographic, production and marketing parameters. Dissertation submitted in partial fulfilment of Bachelor of Science in Agricultural Education. Botswana College of Agriculture. Botswana.

Monau, P. I., Visser, C., Nsoso, S. J. and Van Marle-Köster, E. (2017). A survey analysis of indigenous goat production in communal farming systems of Botswana. *Tropical Animal Health and Production* 49 (6):1265–1271.

Mwacharo, J. M. and Drucker, A. G. (2005). Production objectives and management strategies of livestock keepers in south-east Kenya: Implications for a breeding programme. *Tropical Animal Health and Production*. 37:635-652.

Nsoso, S. J and Rabasima, M. C. (2004). A survey of traditional beef cattle farmers in southern Botswana: Demographic parameters and adoption of certain improved management practices. *South. African Journal Agricultural extension*. 33:11-19.

Nsoso, S. J., Mannathoko, G. and Modise, K. (2005). Monitoring production, health and marketing of indigenous Tswana pigs in Ramotswa village of Botswana. *Livestock Research for Rural Development.* 18.

Nsoso, S. J., Podisi, B., Otsogile, E., Mokhutshwane, B. S. and Ahmadu, B. (2004b). Phenotypic characterization of indigenous Tswana goats and sheep breeds in Botswana: Continuous traits, *Tropical Animal health and Production*, 36: 789-800.

Odugbo, M. O., Odama, L. D., Umoh, J and Lamorde, A. G. (2006). Pasteurella multocida pneumonic infection in sheep: Prevalence, clinical and pathological studies. *Small Ruminant Research* 66:273-277.

Onzima, R. B., Gizaw, S., Kugonza, D. R., van Arendonk, J. A. M. and Kanis, E. (2018).

Production system and participatory identification of breeding objective traits for indigenous goat breeds of Uganda. *Small Ruminant Resources* 163: 51-59.

Peacock, C. (2005). Goats-A pathway out of poverty. *Small Ruminant Research* 60:179-186

Statistics Botswna (2016). Agricultural census stats brief of 2015. Gaborone, Botswana http://www.statsbots.org.bw/sites/default/files/Botswana Agriculture Census Report Final 2015..pdf

Solomon, A. G. (2007). In-situ characterization of Gumuz sheep under farmer's management in north-western lowlands of Amhara region. MSc. Thesis, Haramaya University, Ethiopia. 108p.

Tam, V. W. Y and Le, K. N. (2006). Environmental assessment by power spectrum. Sustainable Development through Culture and Innovation: Executive Summaries. The Joint International Conference on Construction Culture, Innovation and Management (CCIM); 2006 Nov 26-29; Dubai.

Taye, M., Yilma, M., Mengistu, S., Abiso T., Bassa, Z., Wolde, S., Rischkowsky, B., Dessie, T., Okeyo, M., Mekuriaw, G. and Haile, A. (2016). Characterization of production system and breeding practices of sheep producers in Doyogena district, Southern Ethiopia. *African Journal Agricultural Research* 11 (52), 5192-5201.

Van Marle-Koster, E., Visse, C., Makgahlela, M. and Cloete, S. W. P. (2015). Genomic technologies for food security: A review of challenges and opportunities in Southern Africa. *Food Resource International* 76:971-979.

Verbeek, E., Kanis, E., Bett, R. C and Kosgey, I. S. (2007). Socio-economic factors influence small ruminant breeding in Kenya. *Livestock Research for Rural development* 19: 1-11.

Woods, J. and Sekhwela, M. B. M. (2012). The Vegetation Resources of Botswana's Savannas: An Overview. South African Geographical Journal. 85:1, 69-79.

Wurzinger, M., Ndumu, D., Maumung, R. Drucker, A.G., Okeyo, A. M., Semambo, D.K. and Sölkner, J. (2006). Assessing stated preferences through use of choice experiments: valuing (re) production versus aesthetics in the breeding goals of Ugandan Ankole cattle breeds.pp.1-4. *In: Proceedings of the 8th World Congress on genetics applied to Livestock production, 13- 18 August, 2006*. Belo Horizonte, Brazil.

Zewdu, E. (2008). Characterization of Bonga and Horro indigenous sheep breeds of smallholders for designing community based breeding strategies in Ethiopia. MSc thesis submitted to the department of animal science, school of graduate studies, Haramaya University .33p.

Zewdu, W., Workineh, A. and Sölkner, J. (2006). Breeding Scheme based on Analysis of Community breeding Objectives for Cattle in North-western Ethiopia. *Ethiopian Journal of Animal Production* 6:33-66.

Zobell, D., Chapman, C. K and Despain, D. (2019). Applying principles of crossbreeding to maximise Hybrid Vigor. Animal Health, Utah State University. Retrieved from https://www.extension.usu.edu

Zonabend König, E., Mirkena, T., Strandberg, E., Audho, J., Ojango, J., Malmfors, B., Okeyo, A. M., Philipsson, J. (2015). Participatory definition of breeding objectives for sheep breeds under pastoral systems—the case of Red Maasai and Dorper sheep in Kenya. *Tropical Animal Health Production* 48:9–20.

CHAPTER 4

On-farm phenotypic characterization of indigenous Tswana sheep population in selected Districts of Southern Botswana

4.1. Abstract

This study was initiated to phenotypically characterize indigenous Tswana sheep under its natural environment and develop a prediction equation for body weight using linear body measurements in Kgatleng, Kweneng, Southern and South-East districts of Botswana. Multistage purposive random sampling based on sheep population and distribution was used for selection of districts. Data on qualitative characters and quantitative measurements were made on 665 sheep stratified by dentition into four age categories of 0PPI, 1PPI, 2PPI and ≥3PPI to represent ages 6-11, 12–24, 25–36 and above 36 months, respectively. Both qualitative and quantitative data were analyzed using Statistical Analysis System. Most Tswana sheep were characterized by plain coat color pattern with white dominated and plain white colors, short-fat tails with a straight tip pointing downwards, horizontal ears, no horns and wattles. District, sex and age had a significant influence on body weight and most linear body measurements. The body weight of sheep increased gradually as the sheep advanced in age. Tswana males were superior to females in body weight and most linear body measurements. There were positive and significant correlations observed between body weight and other LBMs for both sexes. The highest correlation between body weight and heart girth for both sexes indicate that heart girth explained more variation than other measurements thus is the best variable for predicting body weight in both sexes. The best predicted body weight model for males is $y=-64.15+1.28x$ and $y=-53.47+1.14x$ for females where x and y are heart girth and body weight, respectively. The present study reveals existence of diversity of sheep genetic resources across districts which indicates their potential response to selection.

Keywords: Body weight, Characterization, Morphometric traits, Tswana sheep

4.2. Introduction

Indigenous sheep are widely distributed in the tropics and subtropics due to their unique adaptive features that enable them to fit in a wide variety of environments (Rege *et al*., 2002). In Botswana, the indigenous sheep constitute about 195 000 of the 300 000 national flock (Botswana Statistics, 2016) and is adapted to different geographical regions of the country. It contributes significantly to the livelihoods of resource poor farmers by providing meat and milk as a source of nutrition to the household, and income which is used for a wide range of economic activities. Indigenous Tswana Sheep retain certain adaptive features such as drought, heat and disease tolerance (Nsoso *et al*., 2004b). Very little has been done towards improvement and characterization of Tswana Sheep. The major threat facing indigenous Tswana sheep genetic resources is uncontrolled breeding with exotic breeds or breed replacement with exotic breeds carried out in an endeavor to improve the breed to meet current market demands for more mutton.

It is therefore very important to develop strategies for sustainable utilization of Tswana sheep genetic resources. The prerequisite to developing these strategies is the characterization of the genetic resource under its natural environment (Msanga *et al*., 2012; Monau *et al*., 2018). Phenotypic characterization of local genetic resources is essential for conservation, breed inventory and monitoring, policy formulation and design of breeding programmes (Baker and Gray, 2004). Phenotypic characterization of indigenous Tswana sheep was undertaken more than a decade ago and may not reflect the current situation due to changes in production systems and within population’s changes resulting from evolutionary forces (Sölkner *et al*., 1998). Morphological and productive aspects in a population evolve over time as a result of natural and artificial selection, mutation, migration, and random genetic drift (Song *et al*., 2006). Differences in environment and differences in climatic factors such as rainfall and temperatures also influence adaptive features of local populations which might result in phenotypic differences in the general population (Schierenbeck, 2017). There is therefore need to carry out routine inventories and monitoring of the indigenous Tswana sheep genetic resource. The aim of this was therefore to phenotypically characterize indigenous Tswana sheep under its native environment and to develop a prediction equation for body weight by using linear body measurements in the Kgatleng, Kweneng, Southern and South-East districts of Botswana.

4.3. Materials and methods

4.3.1. Description of the study area

The study was conducted in Kgatleng (24°15'S 26°30'E with total land area of 7,960 km^2) Kweneng (24°00'S 25°00'E with total land area of 35,890 km^2), South East (25°00'S 25°45'E with total land area of 1,780km^2) and Southern (25°00'S 25°00'E with total land area of 28, 470km^2) districts of Botswana from November 2020 to January 2021. The climate in the four districts is mainly semi-arid with high temperatures occurring from October to April and low temperatures occurring from around May to August. Rainfall is low, unreliable highly variable from one year to the next and not evenly distributed. The vegetation type in all districts is savannah with tall grasses, bushes and trees (Woods and Sekhwela, 2012).

4.3.2. Sampling method

A multi-stage purposive sampling technique was employed for selection of districts for the study. In the first stage, discussions were held with district agricultural officers of the Department of veterinary services to know the distribution of indigenous Tswana sheep population in each study district. The four districts (Kgatleng, Kweneng, South-East and Southern) were purposely selected for morphological characterisation based on the distribution of indigenous Tswana sheep. Random sampling was used to select villages within districts and farms/households within villages. Six villages per districts were randomly selected and four to five farms per village were also randomly selected for the study. One to six unrelated animals were sampled per household.

4.3.3. Data collection procedures

A total of six hundred and sixty five (665) (Table 4.2) sheep were used for phenotypic characterisation. Morphological features were recorded for every animal sampled following breed morphological characteristics descriptor guidance list of FAO (2012). Visual observations of qualitative traits such as coat colour, presence of wattles and presence of horns were recorded. Quantitative traits [heart girth (HG), body length (BL), wither height (WH), rump width (RW), ear length (EL), tail length (TL), tail circumference (TC), head length (HL), head width (HW), shoulder width (SW), cannon bone length (CBL), cannon bone circumference (CBC), neck length (NL), rump length (RL), rump height (RH) and scrotal circumference (SC) (in males)] were measured using a flexible tailor's measuring tape calibrated in centimetres (cm). All measurements were taken early in the morning to avoid the effect of feeding and watering on the animal's size. The animals were restrained in an upright unforced plane position during data collection. All measurements were taken by the same personnel in all the districts for consistency.

Each experimental animal was identified by its sex, age and sampling site (district). Sex was characterized as females, rams and castrates. The age of each animal was estimated based on farmers' information and dentition following the procedure described for African sheep by Wilson & Durkin, (1984). Sheep were classified into four age groups: no pair of permanent incisors (0PPI), one pair of permanent incisors (1PPI), two pairs of permanent incisors (2PPI), and three and above pairs of permanent incisors (≥3PPI) to represent the ages of 6-11, 12–24, 25–36 and above 36 months, respectively.

4.3.4. Statistical analysis

Qualitative data from individual observation were analysed following the frequency procedures of Statistical Analysis System (SAS release 9.1 2003). The General Linear Model (GLM) procedures of Statistical Analysis System (SAS, release 9.1 2003) were used to estimate least squares means and standard errors of quantitative linear body measurements. Sex, district and age group of the sheep were fitted as fixed effects, while body weight and linear body measurements (except scrotal circumference) were fitted as dependent variables. Scrotal circumference was analysed by fitting age and district as fixed factors for intact males. Least square means and their corresponding standard errors were calculated for fixed effects of sex, age, district and the age by sex interaction for each body trait.

Model used for the least square mean analysis of body weight and other linear body measurements in females and males except scrotal circumference was:

$$Y_{ijk} = \mu + A_i + D_j + S_k + (AxD)_{ij} + (AxS)_{ik} + (DxS)_{jk} + e_{ijk}$$

Where: Y_{ijk} = Observed body weight or linear measurements

μ = Overall mean

A_i = the fixed effect of i^{th} age groups (i = 0PPI, 1PPI, 2PPI and ≥ 3PPI)

D_j = the fixed effect of j^{th} district (j= Kgatleng, Kweneng, South-East and Southern districts)

S_k = the fixed effect of the k^{th} sex (k= male, female)

$(AxD)_{ij}$= the effect of the interaction of *i* of age group with *j* of district

$(AxS)_{ik}$= the effect of the interaction of *i* of age group with *k* of sex

$(DxS)_{jk}$= the effect of the interaction of *j* of district with *k* of sex

e_{ijk}= random residual error

Model used for the least square mean analysis in males for scrotal circumference was:

$$Y_{ijk} = \mu + A_i + D_j + (AxD)_{ij} + e_{ijk}$$

Where: Y_{ijk} = Scrotal circumference

μ = Overall mean

A_i = the fixed effect of i^{th} age groups (i = 0PPI, 1PPI, 2PPI and ≥ 3PPI)

D_j = the fixed effect of j^{th} district (j= Kgatleng, Kweneng, South-East and Southern districts)

$(AxD)_{ij}$= the fixed effect of the interaction of i^{th} age group with j^{th} of district

e_{ijk}= random residual error

4.3.5. Correlations and regression

Pearson's correlation coefficients of indigenous Tswana sheep were estimated between body weight and other linear body measurements (LBMs) within each sex using the procedure correlation (PROC CORR) of Statistical Analysis System (SAS, release 9.1 2003) to describe the strength and direction of relationships between the response variable (live body weight) and explanatory variables (LBMs). Body weight and other LBMs (BL, HG, WH, RH, SW, EL, RL, CBC, CBL, NL, RW, HW, HL, TL, TC and SC) were included for males whereas SC was excluded when calculating correlations coefficients for female sheep. Based on the correlations of body weight with other LBMs, a stepwise regression procedure (PROC REG) of Statistical Analysis System (SAS, release 9.1 2003) was then used to regress body weight for each sex in order to determine the best-fit regression equation for the prediction of body weight using LBMs. The best-fit models were selected based on the coefficient of determination (R^2) and the simplicity of measurements of the LBMs under field conditions. The following models were used for the analysis of multiple linear regressions.

For males:

$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12}$

$+ \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} +$ ej

Where:

Y_j =the response variable (body weight)

β_0 = the intercept

X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15} *and* X_{16} are the explanatory variables BL, HG, WH, RH, SW, EL, RL, CBC, CBL, NL, RW, HW, HL, TL, TC and SC, respectively.

$\beta_1, \beta_2 \ldots \beta_{16}$ are the regression coefficients of the variables $X_1, X_2 \ldots X_{16}$.

e_j = the residual random error.

For female:

$Y_j = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12}$

$+ \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + e_j$

Where:

Y_j =the response variable (body weight)

β_0 = the intercept

X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14} and X_{15} are the explanatory variables BL, HG, WH, RH, SW, EL, RL, CBC, CBL, NL, RW, HW, HL, TL, and TC, respectively.

$\beta_1, \beta_2 \ldots \beta_{16}$ are the regression coefficients of the variables $X_1, X_2 \ldots X_{15}$.

e_j = the residual random error.

The step-wise regression procedures of Statistical Analysis System (SAS, release 9.1 2003) were used to develop prediction equations used for body weight (BW) in Tswana sheep. The prediction of body weight for Tswana sheep was based on the regression equations y= -64.15+1.28x for males and y= -53.47+1.14x for females where, x and y are heart girth and body weight, respectively.

4.4. Results and Discussion

4.4.1. Qualitative Morphometric traits

Table 4.1 shows some qualitative characters of both male and female indigenous Tswana sheep raised in Kgatleng, Kweneng, South-East and Southern districts of Botswana. There was variation on coloration patterns amongst the sheep populations with predominantly plain coat colour (81.25%) across districts, followed by patchy and spots of different colours (Figure 4.1). The results are consistent with the findings of Asaminew *et al*., (2016), Edea *et al*., (2010) and Tibbo and Ginbar (2004) for Bonga, Horro and Woliata sheep types of Ethiopia. The higher proportion of animals with white dominated coat colour and plain white coat colour could be a reflection of natural selection for animals manifesting white colour to withstand the hot environment of Botswana. This observation is different in other part of the African continent such as Ethiopia where Hailemariam *et al*., (2018) reported the dominance of black coat colour for Gamogofa sheep which helps in absorption of solar radiation to maintain an optimum body temperature in the cold Gamogofa zone.

Most of sheep across the districts had a characteristic short fat tail with a straight tip pointing downwards (Figure 4.1). The fat tail is an adaptive attribute that serves as an energy reserve to enable indigenous Tswana sheep to adapt and survive feed fluctuation periods throughout the year (Ermias *et al*., 2002). This characteristic has also been reported in some South African sheep breeds including the South African Namaqua Afrikaner, the Zulu and the Pedi sheep (Soma *et al*., 2012). To the contrary, Getachew *et al*., (2010) reported short fat tails curved upwards in Menz sheep of Ethiopia. Contrary to the current study, Gizaw *et al*., (2007) and Edea *et al*., (2010) who reported a long fat tail characteristic in Adilo and Bonga sheep of Ethiopia. Differences between tail types is associated with genetic variations of sheep types (Ermias *et al*., 2002). The predominant ear form or orientation observed in indigenous Tswana sheep (overall 98.65%) was horizontal ear orientation. Almost all sheep across districts (97.2% for Kgatleng, 100% for Kweneng, 100% for South-East and 98.3% for Southern district) had no wattles. The findings are similar to Gamogofa sheep of Ethiopia (Hailemariam *et al*., 2018) and a lower proportion of Tswana sheep with wattles in Kgatleng and South-East district is consistent with Melesse *et al*., (2013); Tibbo and Ginbar (2004) for Bonga sheep of Ethiopia. A comparatively high proportion of indigenous Tswana sheep across districts did not have horns and a high proportion of sheep with horns had their horns curving backwards as opposed to straight.

a) Typical example of indigenous Tswana ram

b) Typical example of indigenous Tswana ewe

c) Typical example of indigenous Tswana castrates

Figure 4.1 a, b, c: Typical examples of indigenous Tswana sheep with different color patterns.

Table 4.1 Percentage values for some qualitative traits observed on indigenous Tswana sheep in Southern Botswana

Trait	Kgatleng (%)	Kweneng (%)	South-East (%)	Southern (%)
Coat colour pattern				
Plain	84	81	81	74
Patchy	11	11	12.7	19
Spotted	5	8	6.3	7
Colour type				
White	29.57	25.47	30.19	21.93
Black	4.35	NR	2.83	NR
Brown	4.35	7.55	NR	2.63
White dominant	31.30	52.83	50	61.40
Black dominant	5.22	0.94	4.72	0.88
Brown dominant	14.78	14.15	12.26	14.04
Hair type				
Short and smooth	47.1	52.1	43.4	44.7
Long and course	19.5	21.2	29.3	22.4
Short and course	33.4	26.7	27.3	32.9
Tail type				
Short fat	41.1	53.2	43.1	38.1
Long fat	18.3	4.6	27.3	10
Short thin	NR	3.5	NR	NR
Docked	40.9	38.7	29.8	51.9
Tail form				
Curved at the tip	17.1	13.2	14.7	10.2
Straight at the tip	42	48.1	55.5	37.9
Docked	40.9	38.7	29.8	51.9
Ear form				
Horizontal	98.1	98.4	100	98.1
Semi-pendulous	1.9	1.6	NR	1.6
Rudimentary				
Wattle				
Present	2.8	NR	NR	1.7
Absent	97.2	100	100	98.3
Horn				
Present	8.4	4.6	8.0	7.2
Absent	91.6	95.4	92	92.8
Horn Shape				
Straight	13	NR	22	NR
Curving backwards	87	100	78	100

NR= Not recorded

4.4.2. Flock structure

Table 4.2 shows the flock structure of indigenous Tswana sheep in Kgatleng, Kweneng, South-East and Southern districts of Botswana. Generally, the proportion of female sheep increased with age, hence females out-numbered males (rams and castrates) across all age groups except for the 6-11month age group (Table 4.2). This is because selection of breeding rams is mostly done after 12 months of age after the rams had reached sexual maturity. Rams that have not been selected for breeding are mostly castrated or culled while almost all females are retained for breeding purposes. A few males are selected for breeding purposes based on favourable desired traits while culls are sold for meat production or to other farmers who further do some selection to suit their farming needs (Nsoso *et al*., 2004b). Again, the traditional meat mark*et al*so requires animals of an older age group (>12 months) to attract a favourable price (Nsoso and Madimabe, 1999). Similar findings have been previously reported by Katongole *et al*., (1996) on goats and Nsoso *et al*., (2004b) on goats and sheep.

Table 4.2 Flock structure of indigenous Tswana sheep measured in the surveyed districts of Southern Botswana.

District	**Fixed effect Age**	**Female**	**Rams**	**Castrates**	**Overall**	**% composition**
Kgatleng	6-11 months	14	6	3	23	14.0
	12-24 months	53	4	4	61	37.2
	25-36 months	39	4	3	46	28.0
	>36 months	29	3	2	34	20.7
Kweneng	6-11 months	11	6	5	22	14.4
	12-24 months	48	6	4	58	37.9
	25-36 months	32	4	4	40	26.1
	>36 months	27	3	3	33	21.6
South-East	6-11 months	09	5	3	17	12.7
	12-24 months	39	3	3	45	33.6
	25-36 months	31	3	2	36	26.9
	>36 months	31	3	2	36	26.9
Southern	6-11 months	17	7	8	32	14.9
	12-24 months	65	6	5	76	35.3
	25-36 months	47	7	4	58	27
	>36 months	42	5	2	49	22.8
Total					**665**	**100%**

4.4.3. Effect of sex on body weight and linear body measurements

The sex of the animal had a significant effect on body weight and most linear body measurements except ear length, neck length and cannon bone circumference across the four districts (Appendix B). Similar findings have been reported by Kunene *et al*., (2007) in Zulu sheep of South Africa and Shibabaw (2012) in Hararghe highland sheep of Ethiopia. To the contrary, Asefa *et al*., (2017) reported a non-significant effect of sex on body weight and some linear body measurements in Bale Zone sheep of Ethiopia.

4.4.4. Effect of district on body weight and linear body measurements

The least square means and standard errors for the effect of district on live body weight and other linear body measurements of indigenous Tswana sheep are presented in Table 4.3. The district effect was significant ($P<0.05$) for body weight and most linear body measurements except cannon bone circumference. The significant district effect on body weight and linear body measurements is consistent with Asefa *et al*., (2017), Alemayehu (2011), Kunene *et al*., (2007). Southern district sheep were the heaviest (38.93±0.55 kg) and Kweneng sheep were the lightest (34.14±0.53 kg). Generally, Tswana sheep were comparable in body weight to Zulu sheep (39.76 kg to 40.26 kg) (Kunene *et al*., 2007) and heavier than several indigenous sheep of Ethiopia (Asaminew *et al*., 2016; Michael *et al*., 2016; Mohammed *et al*., 2017). Tswana sheep are however lighter than Balami and Uda sheep types from South, Middle belt and North West districts of Nigeria (Agaviezor *et al*., 2012).

Southern district sheep had significantly ($P<0.05$) higher heart girth than sheep in Kgatleng, Kweneng and South-East districts of Botswana (Table 4.3). The difference in heart girth between sheep in different regions has also been reported by Asaminew *et al*., (2016) who found higher heart girth in Soddo Zuria and Damote Gale sheep than Damote Sore sheep of Ethiopia. Generally Tswana sheep had similar heart girth with Uda sheep of Nigeria (Agaviezor *et al*., 2012) and Hulet eju sheep in Ethiopia (Michael *et al*., 2016). The heart girth of Tswana sheep in the Southern district was higher than the heart girth of sheep in Wogide, Borena and Legambo districts of Ethiopia (Mohammed *et al*., 2017) and Sinan and Hulet eju sheep of Ethiopia (Michael *et al*., 2016). Southern district Tswana sheep had the longest body length than sheep from other districts while Kweneng district sheep were the shortest. Body length of Tswana sheep in Kgatleng, Kweneng and Southern sheep were similar to those of Gozamen, Sinan and Hulet-eju sheep of Ethiopia (Michael *et al*., 2016) and longer than that of Borena and Legambo sheep of Ethiopia (Mohammed *et al*., 2017). Generally, Tswana sheep across the districts were shorter than Soddo Zuria and Damote Gale of Southern Ethiopia (Asaminew *et al*., 2016).

South-East and Southern district Tswana sheep had similar wither height and were significantly ($P<0.05$) taller than Kgatleng and Kweneng sheep which also had similar wither height. South-East and Southern district Tswana sheep had similar wither height to Borena sheep of Ethiopia (Mohammed *et al*., 2017) and Agarfa sheep of Ethiopia (Asefa *et al*., 2017). Generally, Tswana sheep are taller than Metta, Gorogutu and Deder sheep of Ethiopia (Shibabaw, 2012) and Damote Sore sheep of Ethiopia (Asaminew *et al*., 2016) and shorter than Gozamen, Sinan and Hulet eju sheep of Ethiopia (Michael *et al*., 2016). The differences in body weight and other linear body measurements could be as a result of differences breed structure emanating from in the influences of evolutionary forces of the world. Other differences in body weight and other linear body measurements could be due to nutritional and management practices between districts. In females, the pregnancy status of the animal could be another reason for variations in body weight and other linear body measurements especially body length (Kunene *et al*., 2007). The wide variations in body weight and other linear body measurements of sheep between districts (see coefficient of variation, CV%, in appendix A) indicate healthy diversity which could be exploited in genetic improvement programmes of indigenous Tswana sheep (Berhanu and Haile, 2009).

Kgatleng and Kweneng rams had similar scrotal circumference that were significantly higher than scrotal circumference of sheep in South-East and Southern districts. The significance influence of district on scrotal circumference of Tswana sheep found in the current study is contrary to Mohammed *et al*., (2017) for Wogide, Borena and Legambo rams of Ethiopia and Michael *et al*., (2016) for Gozamen, Sinan and Hulet eju rams of Ethiopia who reported a non-significant influence of district on ram scrotal circumference. Scrotal circumference of Tswana sheep in Southern and South-East districts of Botswana is similar to that of Wogide and Legambo rams (Mohammed *et al*., 2017) and Zulu rams (Kunene *et al*., 2007). Generally, the scrotal circumference of Tswana rams was higher than that of Borena rams of Ethiopia (Mohammed *et al*., 2017) and Soddo Zuria, Damote Gale and Damote Sore rams of Ethiopia (Asaminew *et al*., 2016).

Scrotal circumference is a good indicator of a ram's breeding ability and an indirect selection criterion of rams (Duguma *et al.*, 2002). Rams with larger scrotal circumferences produce more and higher quality semen than rams of the same age and breed with smaller scrotal circumferences. Therefore, rams from Kgatleng and Kweneng have a greater potential of being selected for breeding purposes on genetic improvement schemes based on their larger scrotal circumference. Differences in scrotal circumference between breeds and districts might be due to the fact that testicular size varies with breed, age of an animal and season/time of the year (Söderquist and Hulten, 2006). Kunene *et al*., (2007) reported larger scrotal circumference in autumn and in summer compared to winter and spring in Zulu rams, probably because of fluctuations in fodder quality and quantity with changes in times of seasons of the year. Furthermore, Dana *et al*., (2000) reported reduced scrotal circumference by up to 10% in Ethiopian highland sheep fed low quality diet than those fed good quality diet. Low quality diet causes loss of fat from scrotal tissue of rams resulting in reduced testicular size (Coulter and Kozub, 1984).

Table 4.3 Least square means of quantitative morphometric traits of indigenous Tswana sheep in the four districts of Southern Botswana (means±SD)

Traits	Kgatleng	Kweneng	South-East	Southern
BW (kg)	$37.41^{a}\pm0.59$	$34.14^{b}\pm0.53$	$34.94^{b}\pm0.54$	$38.93^{a}\pm0.55$
HW (cm)	$11.11^{a}\pm0.12$	$9.55^{c}\pm0.11$	$10.61^{b}\pm0.12$	$9.24^{c}\pm0.12$
HL (cm)	$14.04^{a}\pm0.17$	$12.94^{bc}\pm0.15$	$13.21^{b}\pm0.16$	$12.76^{c}\pm0.16$
EL (cm)	$12.25^{a}\pm0.12$	$11.22^{b}\pm0.12$	$11.17^{bc}\pm0.12$	$10.89^{c}\pm0.12$
SW (cm)	$22.77^{a}\pm0.34$	$21.73^{b}\pm0.32$	$23.11^{a}\pm0.33$	$21.79^{b}\pm0.32$
NL (cm)	$31.06^{b}\pm0.43$	$28.73^{c}\pm0.40$	$32.25^{a}\pm0.41$	$30.07^{b}\pm0.40$
CBC (cm)	7.81±0.54	7.83±0.50	7.00±0.51	7.11±0.50
CBL (cm)	$15.43^{ab}\pm0.14$	$14.91^{c}\pm0.13$	$15.73^{a}\pm0.14$	$15.26^{bc}\pm0.13$
HG (cm)	$78.72^{b}\pm0.78$	$77.24^{b}\pm0.72$	$78.06^{b}\pm0.74$	$81.00^{a}\pm0.73$
BL (cm)	$62.56^{ab}\pm0.62$	$61.36^{b}\pm0.57$	$62.18^{ab}\pm0.59$	$63.18^{a}\pm0.58$
WH (cm)	$64.69^{b}\pm0.52$	$64.59^{b}\pm0.48$	$66.28^{a}\pm0.49$	$65.62^{ab}\pm0.48$
RL (cm)	$23.22^{bc}\pm0.29$	$22.53^{c}\pm0.27$	$23.72^{b}\pm0.27$	$25.56^{a}\pm0.27$
RH (cm)	$64.46^{bc}\pm0.52$	$64.20^{b}\pm0.49$	$65.91^{a}\pm0.50$	$65.70^{ac}\pm0.49$
RW (cm)	$16.79^{a}\pm0.22$	$14.89^{c}\pm0.20$	$15.93^{b}\pm0.21$	$16.5^{ab}\pm0.20$
TL (cm)	$34.92^{ac}\pm0.86$	$35.77^{a}\pm0.78$	$35.52^{a}\pm0.69$	$33.25^{bc}\pm0.75$
TC (cm)	$17.88^{b}\pm0.78$	$19.89^{b}\pm0.71$	$22.27^{a}\pm0.62$	$19.49^{b}\pm0.68$
SC (cm)	$26.09^{ab}\pm0.76$	$28.12^{a}\pm0.79$	$24.27^{b}\pm0.95$	$24.50^{b}\pm1.11$

^{a,b,c} Means across rows between districts with different superscript letters are significantly ($P<0.05$) different BW=Body weight, BL= body length, HG=Heart girth, SW=Shoulder width, WH=Wither height, CBC=Cannon bone circumference, CBL=Cannon bone length, NL=Neck length, Rump length, RW=Rump width, RH=Rump height, HW=Head width, HL=Head length, EL=Ear length, TL=Tail length, TC=Tail circumference and SC=Scrotal circumference

4.4.5. Effect of sex and age group interaction on body weight and linear body measurements

The least square means and standard errors for the effect of sex, age group and their interaction on body weight and other LBMs of indigenous Tswana sheep are presented in Table 4.4. The interaction of sex and age group was significant ($p<0.05$) for body weight and most LBMs (BL, HL, HW, SW, CBL, HG, WH, RL, RH, RW, TL and TC). However, the interaction effect was not significant ($P>0.05$) for cannon bone circumference and ear length, implying that these parameters were not affected by the sex by age group interaction in the current study. In consonance with Tassew (2012) the sex by age group interaction was significant ($P<0.05$) for most LBMs except ear length in Habru and Gubalafto sheep. Contrary to the current findings, Michael *et al*., (2016) and Alemayehu (2011) reported a significant sex by age group interaction ($P<0.01$) only for body weight in Dawro and Konta Special Woreda zones of Ethiopia. Kunene *et al*., (2007) also reported a non-significant sex by age interaction for LBMs between Zulu rams and ewes lambs of South Africa at their milk stage.

The sex by age interaction found in the current study revealed that the differences in live body weight between males and females increased with the age of the animals to 4.22 kg, 4.51 kg, 6.04 kg and 7.35 kg between rams and ewes at zero, one, two and three pairs of permanent teeth, respectively (Table 4.4). Body weights obtained at 0PPI, 1PPI and ≥3PPI age groups in the current study were slightly higher than those previously reported by Nsoso *et al*., (2004b). The 2PPI age group in the current study had lower body weights than those reported by Nsoso *et al*., (2004b). The discrepancies might be mainly due to differences in management and evolving production systems and changing breeding goals of Tswana sheep farmers.

Generally, males were heavier and had higher LBMs than females across all age groups except ear length at 2PPI and ≥3PPI. This is consistent with Getachew *et al*., (2010) for Menz and Afar sheep and Tibbo *et al*., (2004) for Menz and Horro sheep in Ethiopia. The superiority of males over females in body weight and other LBMs might be attributed to differences in hormonal profiles between the sexes with males having hormones that promote rapid weight gain and muscularity than females, consequently resulting in superior body weight and higher LBMs in males than females (Gebreyowhens and Tasfay 2016). In females, estrogen inhibits growth of long bones of the body resulting in slower growth rate and the reaching puberty at a relatively smaller body size (Sowade and Sobola 2007).

Table 4.4 Effect of age by sex interaction on body weight and linear body measurements of indigenous Tswana sheep in the Southern part of Botswana

	0-12			13-24			25-36			>36		
Trait	**Female**	**Ram**	**Castrate**	**Female**	**Ram**	**Castrate**	**Female**	**Ram**	**Castrate**	**Female**	**Ram**	**Castrate**
BW (kg)	24.32±0.76^{b}	28.54±0.97^{a}	25.40±1.27^{b}	32.70±0.72^{b}	37.21±1.09^{a}	34.82±1.35^{ab}	35.66±0.64^{b}	41.70±1.18^{a}	39.62±1.38^{a}	39.59±0.50^{b}	46.94±1.03^{a}	47.12±1.27^{a}
BL (cm)	55.44±0.66^{b}	58.80±0.82^{a}	55.52±0.86^{b}	61.15±0.61	62.38±0.96	61.36±0.91	62.03±0.54^{b}	64.03±0.98^{ab}	64.21±0.93^{a}	64.93±0.43^{b}	67.26±0.82^{a}	67.04±0.86^{a}
HG (cm)	68.13±0.71^{b}	72.26±0.89a	70.30±0.92^{ab}	75.32±0.66^{b}	79.05±1.01^{a}	78.73±0.98^{a}	78.32±0.58^{b}	82.03±1.06^{a}	81.52±1.06^{a}	81.72±0.46^{b}	86.39±0.89^{a}	87.10±0.92^{a}
SW (cm)	17.81±0.36^{b}	20.04±0.44^{a}	20.50±0.46^{a}	20.33±0.33^{b}	21.52±0.50^{a}	21.84±0.49^{a}	21.12±0.29^{b}	23.00±0.52^{a}	23.67±0.50^{a}	22.24±0.23^{b}	26.67±0.44^{a}	27.00±0.46^{a}
WH (cm)	58.44±0.69^{b}	61.63±0.85^{a}	60.60±0.89^{ab}	62.63±0.63^{b}	65.38±0.37^{a}	65.00±0.95^{a}	62.75±0.56^{b}	67.53±1.02^{a}	66.19±0.97^{a}	65.96±0.44^{b}	72.07±0.85^{a}	71.04±0.89^{a}
CBC (cm)	7.88±0.74	6.98±0.92	6.86±0.96	6.83±0.68	7.21±1.04	7.11±1.02	7.13±0.59	7.71±1.10	7.33±1.04	8.19±0.49	8.00±0.92	7.74±0.96
CBL (cm)	13.54±0.15^{b}	14.43±0.19^{a}	14.04±0.20^{a}	14.46±0.14^{b}	15.50±0.22^{a}	15.09±0.21^{a}	15.22±0.12^{b}	15.74±0.23^{a}	15.79±0.22^{a}	15.57±0.10^{b}	17.06±0.19^{a}	16.64±0.20^{a}
NL (cm)	25.35±0.46^{b}	27.52±0.57^{a}	26.00±0.60^{ab}	28.35±0.43^{b}	29.93±0.65^{a}	30.50±0.64^{a}	30.88±0.37^{b}	31.63±0.68^{ab}	32.74±0.65^{a}	32.40±0.30^{b}	34.19±0.57^{a}	34.52±0.60^{a}
RL (cm)	20.89±0.35	21.20±0.44	21.60±0.45	22.68±0.32^{b}	24.00±0.49^{a}	24.68±0.48^{a}	23.34±0.28	23.94±0.52	23.71±0.49	24.32±0.23^{b}	26.37±0.44^{a}	27.04±0.45^{a}
RW (cm)	14.05±0.27	14.76±0.34	13.88±0.35	15.36±0.25	16.24±0.38	15.55±0.37	16.14±0.22	16.21±0.40	16.33±0.38	16.60±0.17^{b}	18.11±0.34^{a}	18.14±0.35^{a}
RH (cm)	58.24±0.69^{b}	62.19±0.86^{a}	59.72±0.89^{b}	62.29±0.64^{b}	64.90±0.97^{a}	64.41±0.95^{ab}	63.10±0.56^{b}	67.00±1.02^{a}	66.24±0.97^{a}	66.44±0.45^{b}	71.11±0.86^{a}	70.60±0.89^{a}
HW (cm)	8.52±0.17^{b}	9.26±0.21a	8.90±0.22^{ab}	9.35±0.16b	10.24±0.24^{a}	9.77±0.24a^{b}	10.05±0.14^{b}	11.13±0.25^{a}	10.57±0.24^{ab}	10.33±0.11^{b}	11.59±0.21^{a}	11.06±0.22^{a}
HL (cm)	11.30±0.17^{b}	11.91±0.22^{a}	11.38±0.23^{ab}	12.28±0.16^{b}	13.17±0.25^{a}	12.84±0.24^{ab}	13.60±0.14	14.11±0.26	13.64±0.25	13.68±0.11^{c}	15.28±0.22^{a}	14.66±0.23^{b}
EL (cm)	10.51±0.17	10.76±0.21	10.70±0.22	11.39±0.16	10.95±0.24	11.13±0.24	11.82±0.14	11.42±0.26	11.76±0.24	11.83±0.11	11.81±0.21	11.88±0.22
TL (cm)	29.21±1015	31.85±1.09	30.25±1.99	31.79±1.07	34.63±1.41	33.97±1.33	35.67±1.03	35.33±1.33	35.69±1.56	33.48±0.80^{c}	41.14±1.20^{a}	36.88±1.37^{b}
TC (cm)	14.56±0.90^{b}	18.06±0.85^{ab}	18.84±1.56^{a}	17.04±0.83^{b}	19.92±1.10^{a}	18.99±1.04^{ab}	16.03±0.80^{c}	21.57±1.04^{a}	20.81±1.22^{ab}	17.10±0.63^{c}	28.92±0.94^{a}	24.40±1.07^{b}

^{a,b,c} Means across rows between age groups with different superscript letters are significantly (P<0.05) different BW=Body weight, BL= body length, HG=Heart girth, SW=Shoulder width, WH=Wither height, CBC=Cannon bone circumference, CBL=Cannon bone length, NL=Neck length, Rump length, RW=Rump width, RH=Rump height, HW=Head width, HL=Head length, EL=Ear length, TL=Tail length, TC=Tail circumference and SC=Scrotal circumference

4.4.6. Correlation between body weight and other LBMs

Animal live body weight, linear body measurements, their interrelationships and correlations are very important in determining genetic potential for co-current improvement of traits in genetic improvement programs. The phenotypic correlation coefficients between live body weight and linear body measurements in both males and females are presented in Table 4.5. In males, significant (P<0.05), positive and strong correlations were found between body weight and heart girth (r=0.97), followed distantly by rump height (r=0.79) and wither height (r=0.76). These linear body measurements were highly affected by the changes in body weight, hence important in predicting body weight of indigenous Tswana sheep males. Body length (r=0.67), shoulder width (r=0.67), rump length (r=0.66), cannon bone circumference (r=0.69), cannon bone length (r=0.72), neck length (r=0.69), rump width (r=0.72), head width (r=0.60), head length (r=70), tail length (r=55) and tail circumference (r=0.50) showed significant (P<0.05) moderate and positive correlations with body weight. Ear length showed a significant (P<0.05) low and positive correlation while scrotal circumference did not show any significant correlation with body weight.

Likewise, in females, heart girth (r=0.90) showed the strongest significant (P<0.05) and positive correlation with body weight. Most linear body measurements, body length (r=0.51), wither height (r=0.60), rump height (r=0.58), shoulder width (r=0.48), rump length (r=0.50), neck length (r=0.56), rump width (r=0.51) and head length (r=0.48) had significant (P<0.05), moderate and positive correlations with body weight. Ear length (r=0.29), cannon bone length (r=0.45), head width (r=0.39), tail length (r=0.23) and tail circumference (r=0.13) showed significant low correlation with body weight whereas cannon bone circumference had no significant (P>0.05) correlation with body weight. The highest association of heart girth with body weight than other linear body measurements is consistent with Afolayan *et al*., (2006) and Asaminew *et al*., (2016).

Generally, higher correlations coefficients between body weight and other linear body measurements were found in males than females. Selection for body weight will thus result in highest co-current improvements of linear body measurements in males than females. Traits that will benefit more from selecting for higher body weight in both male and female Tswana sheep include heart girth, rump height and wither height. Asefa *et al*., (2017) Asaminew *et al*., (2016) similarly reported heart girth as one of the traits highly correlated to body weight and will thus be significantly improved if selection of sheep is based on body weight.

Table 4.5 Correlations coefficients between body weight and linear body measurements (Above diagonal for male and below diagonal for female)

	BW	BL	HG	WH	RH	SW	EL	RL	CBC	CBL	NL	RW	HW	HL	TL	TC	SC
BW	1	.67*	.97*	.76*	.79*	.67*	.35*	.66*	.69*	.72*	.69*	.72*	.60*	.70*	.55*	.50*	.11^{ns}
BL	.51*	1	.63*	.64*	.66*	.51*	.33*	.47*	.49*	.52*	.57*	.57*	.54*	.55*	.43*	.39*	.09^{ns}
HG	.90*	.51*	1	.76*	.77*	.64*	.29*	.68*	.67*	.72*	.67*	.71*	.56*	.69*	.57*	.50*	.11^{ns}
WH	.60*	.46*	.59*	1	.91*	.65*	.33*	.66*	.62*	.73*	.70*	.69*	.69*	.69*	.69*	.59*	.09^{ns}
RH	.58*	.49*	.61*	.88*	1	.63*	.33*	.69*	.60*	.71*	.72*	.70*	.62*	.66*	.60*	.56*	.08^{ns}
SW	.48*	.36*	.55*	.41*	.44*	1	.40*	.50*	.53*	.59*	.70*	.62*	.68*	.68*	.56*	.58*	.09^{ns}
EL	.29*	.11^{ns}	.30*	.31*	.29*	.31*	1	.22*	.47*	.44*	.40*	.32*	.49*	.50*	.29*	.15*	.11^{ns}
RL	.50*	.43*	.50*	.54*	.57*	.32*	.18*	1	.44*	.58*	.54*	.70*	.40*	.50*	.44*	.44*	-.22^{ns}
CBC	.04^{ns}	-.03^{ns}	.05^{ns}	.02^{ns}	.01^{ns}	-.04^{ns}	.04^{ns}	.001^{ns}	1	.60*	.50*	.58*	.56*	.64*	.50*	.36*	.11^{ns}
CBL	.45*	.40*	.51*	.54*	.57*	.48*	.46*	.36*	-.06^{ns}	1	.70*	.65*	.64*	.69*	.61*	.52*	.10^{ns}
NL	.56*	.36*	.62*	.57*	.54*	.51*	.35*	.41*	-.03^{ns}	.62*	1	.61*	.74*	.70*	.60*	.61*	.13^{ns}
RW	.51*	.34*	.52*	.43*	.38*	.34*	.39*	.29*	-.05^{ns}	.42*	.51*	1	.59*	.64*	.55*	.51*	.06^{ns}
HW	.39*	.20*	.43*	.35*	.33*	.43*	.46*	.08*	.06^{ns}	.48*	.54*	.58*	1	.82*	.56*	.50*	.13^{ns}
HL	.48*	.35*	.56*	.46*	.49*	.45*	.48*	.31*	.04^{ns}	.55*	.51*	.53*	.58*	1	.62*	.53*	.16^{ns}
TL	.23*	.23*	.26*	.32*	.34*	.25*	.20*	.17*	-.02^{ns}	.30*	.22*	.12^{ns}	.19*	.28*	1	.71*	.18^{ns}
TC	.13*	.26*	.18*	.27*	.32*	.22*	.09^{ns}	.23*	-.06^{ns}	.20*	.11^{ns}	.06^{ns}	-.07^{ns}	.02^{ns}	.39*	1	.11^{ns}

BW=Body weight, BL= body length, HG=Heart girth, SW=Shoulder width, WH=Wither height, CBC=Cannon bone circumference, CBL=Cannon bone length, NL=Neck length, Rump length, RW=Rump width, RH=Rump height, HW=Head width, HL=Head length, EL=Ear length, TL=Tail length, TC=Tail circumference and SC=Scrotal circumference; ns=Non-significant (P>0.05); *significant at P<0.05

4.4.7. Prediction of live body weight from other LBMs

Body weight is an important growth indicator and trait of economic importance that influence management interventions (drug doses) and determines the final market value of an animal (Otoikhian *et al*., 2008). The accuracy of functions used to predict live body weight from linear body measurements is of paramount importance in livestock production enterprises (Mohammed *et al*., 2017). For this study, in order to develop the prediction equation, only four linear body measurements (HG, WH, SW and RL) were selected in the prediction equation for rams (Table 4.6) and four linear body measurements (HG, WH, BL and RH) were selected in the prediction equation for ewes (Table 4.7). After comparing all coefficient values for all the relationships between body weight and other LBMs in males and females, heart girth showed the highest association with body weight in both males (0.97) and females (0.90), and thus was selected to predict body weight in each sex. This might be true because heart girth is made up of muscles, some fat and bone structure which are the main constituents of live body weight of an animal (Okpeku *et al*., 2011). Heart girth is deemed an easy variable to measure and is amongst the least affected by the posture of the animal (Mohammed *et al*., 2017). Therefore, low errors are incurred by individuals taking heart girth measurements under field conditions compared to other LBMs.

The prediction of body weight in males can be based on the prediction equation y= -64.15+1.28x and for females y= -53.47+1.14x where, x and y are heart girth and body weight respectively. The fitted prediction models were selected based on higher of coefficient of determination (R^2) and smaller coefficient of variation (CV %). The R^2 is a proportion of the total variability explained by the predicted model. Using heart girth in the model gave R^2 values of 93% in males and 80% in females meaning that heart girth accounted for large proportions of changes in body weight in males and females, respectively. Although there is a slight increase in adjusted R^2 values whenever a new variable is added to the model (Tables 4.6 and 4.7), using heart girth alone to predict body weight might be sufficient and preferable to combinations with other LBMs due to simplicity. This could prove very useful particularly under field conditions where animal restraint might be difficult during measurements. Several authors have reported that heart girth can be a sole predictor of live body weight based on its high correlation coefficients with body weight (Asefa *et al*., 2017; Asaminew *et al*., 2016).

Table 4.6. Multiple regression analysis of live weight on different LBM in males

Model	Parameters						
	Inter	β_1	β_2	β_3	β_4	R^2	Adj R^2
HG	-64.15	1.28	-	-	-	0.93	0.93
HG+WH	-67.45	1.20	0.14	-	-	0.93	0.93
HG+WH+SW	-66.50	1.17	0.09	0.19	-	0.94	0.94
HG+WH+SW+RL	-66.50	1.19	0.11	0.19	-0.10	0.94	0.94

HG= Heart girth; WH= wither height; SW=Shoulder width; RL= Rump length

Table 4.7. Multiple regression analysis of live weight on different LBM in females

Model	Parameters						
	Inter	β_1	β_2	β_3	β_4	R^2	Adj R^2
HG	-53.47	1.14	-	-	-	0.80	0.80
HG+WH	-61.03	1.06	0.21	-	-	0.81	0.81
HG+WH+BL	-62.12	1.03	0.19	0.08	-	0.81	0.81
HG+WH+BL+RH	-61.85	1.05	0.33	0.89	-0.18	0.81	0.82

HG= Heart girth; WH= Wither height; BL= Body length; RH= Rump height

4.5. Conclusion

The most dominant coat color patterns on indigenous Tswana sheep was plain. The white dominant and plain white were the most dominant coat colors in Tswana sheep. Most Tswana sheep were characterized by short fat tails with a straight tip pointing downwards at the end. The predominant ear orientation in Tswana sheep was horizontal. Most Tswana sheep did not have horns and wattles. The study revealed variability in LBMs between sheep in different districts of Botswana. Tswana sheep in the Southern district of Botswana displayed superiority in body weight, body length and heart girth over sheep in other districts. Generally, higher correlation coefficients between body weight and LBMs were observed between in males than females. Heart girth accounted for most of the variability in body weight than other LBMs in both males and females and was thus used as the sole predictor of body weight. The prediction equation for body weight in Tswana sheep males was $y = -64.15+1.28x$ and for females was $y = -53.47+1.14x$ where, x and y are heart girth and body weight, respectively.

4.6. References

Afolayan, R. A., Adeyinka, I. A. and Lakpinin, C. A. M. (2006). The estimation of live weight from body measurements in Yankasa sheep. *Czech Journal of Animal Science* 51(8): 343-348. 51:343-348.

Agaviezor, B. O., Peters, S. O., Adefenwa, M. A., Yakubu, A., Adebambo, O. A., Ozoje, M. O., Ikeobi, C. O .N., Wheto, M., Ajayi, O. O., Amusan, S. A., Ekundayo, O. J., Sanni, T. M., Okpeku, M., Onasanya, G.O., De Donato, M., Ilori, B. M., Kizilkaya, K. and Imumorin, I. G. (2012). Morphological and microsatellite DNA diversity of Nigerian indigenous sheep. *Journal of Animal Science and Biotechnology* 3(1):1-16.

Alemayehu, A. (2011). Phenotypic characterization of indigenous sheep types of Dawuro zone and Konta special woreda of SNNPR, Ethiopia. M.Sc. Thesis presented to the School of Graduate Studies of Haramaya University, Dire Dawa, Ethiopia.

Asaminew, M., Kebede, K and Mekasha, Y. (2016). On farm phenotypic characterization of indigenous sheep types in Woliata Zone, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare* 6(11):114-124.

Asefa, B., Abate, T and Adunga, E. (2017). Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. *Journal of Veterinary Science and Technology* 8 (4):1-7.

Baker, R. L. and Gray, G. D. (2004). Appropriate breeds and breeding schemes for sheep and goats in the tropics. In: Sani, R. A., Gray, G. D., Baker, R. L. (eds.), Worm Control for Small Ruminants in Tropical Asia, Canberra, ACIAR Monograph, 113:63–96.

Berhanu, B. and Haile, A. (2009). Reproductive performance of traditionally managed sheep in the South Western part of Ethiopia. *Livestock Research for Rural Development* 21 (9).

Coulter, G. H. and Kozub, G. C. (1984). Testicular development, epididymal sperm reserves and seminal quality in 2-year-old Hereford and Angus bulls: Effect of two levels dietary energy. *Journal of Animal Science* 59(2): 432-440.

Dana, N., Shenkoru, T. and Tegegne, A. (2000). Growth rates and testicular characteristics of Ethiopian highland sheep offered chickpea haulm supplemented with incremental levels of *Leucaena leucocephala* leaf hay. *Livestock Production Science* 65(3):209-217.

Duguma, G., Cloete, S.W.P., Schoeman, S. J and Jordaan, G.F (2002). Genetic parameters of testicular measurements in Merino rams and the influence of scrotal circumference on total flock fertility. *South African Journal of Animal Science* 32(2): 76-82.

Edea, Z., Haile, A., Tibbo, M., Sharma, A. K., Assefa, D., Sölkner, J. and Wurzinger, M. (2010). Morphological characterization of Bonga and Horro indigenous sheep breeds under smallholder conditions in Ethiopia. *Ethiopian Journal of Animal Production* 9(1): 117–133.

Ermias, E., Yami, A and Rege, J. E. O (2002). Fat deposition in tropical sheep as adaptive attribute to periodic feed fluctuation. *Journal of Animal Breeding and Genetics* 119(4):235-246.

Food and Agriculture Organization (FAO). (2012). Phenotypic characterization of animal genetic resources. FAO Animal Production and Health Guidelines No.11. FAO, Rome, Italy.

Gebreyowhens, W and Tesfay, Y. (2016). Morphological Characterization of Indigenous Highland Sheep Population of Tigray, Northern Ethiopia. *Journal of Natural Sciences Research* 6(1): 96-104.

Getachew, T., Haile, A., Tibbo, M., Sharma, A., Kifle, A., Terefe, E., Wurzinger, M., Sölkner, J. (2010). Morphological characters and body weight of Menz and Afar sheep within their production system. *Ethiopian Journal of Animal Production* 9(1): 99-115.

Gizaw, S., Van Arendonk, J. A. M., Komen, H., Windig, J. J. and Hanotte, O. (2007). Population structure, genetic variation and morphological diversity in indigenous sheep of Ethiopia. *Animal Genetics* 38(6): 621–628.

Hailemariam, F., Gebremicheal, D. and Hadgu, H. (2018). Phenotypic characterization of sheep breeds in Gamogofa zone. *Agriculture and Food Security* 7(1):1–7.

Katangole, J. B. D., Sebolai, B. and Madimabe, M. J. (1996). Morphological characteristics of the Tswana goat. In Lebbie S. H. B.and Kagwini, E. (eds), *Proceedings of the Third Biennial Conference on the African Small Ruminant Research Network UICC,* Kampala, Uganda, 1994, pp. 43-47.

Kunene, N. W., Nesamvuni, E. A. and Fossey, A. (2007). Characterization of Zulu (Nguni) sheep using linear body measurements and some environmental factors affecting these measurements. *South African Journal of Animal Science* 37(1): 11–20.

Melesse, A., Banerjee, S., Lakew, A., Mersha, F., Hailemariam, F., Tsegaye, S. and Makebo, T. (2013). Morphological characterization of indigenous sheep in Southern Regional State, Ethiopia. *International journal of Animal Genetic Resources* 52:39–50.

Michael, A., Kefelegn, K. and Yoseph. M. (2016). Phenotypic Characterization of Indigenous Sheep Types In Northern Ethiopia. *Journal of Natural Sciences Research* 6 (15):16-27.

Mohammed, N., Alemayehu, K. and Getachew, T. (2017). On-farm phenotypic characterisation of indigenous sheep population and its cross with Awassi in Selected Districts of South Wollo, Amhara, Ethiopia. *Tropical Drylands* 1(1):1-11.

Monau, P. I., Visser, C., Nsoso, S. J. and Van Marle-Köster, E. (2018). Phenotypic and genetic characterization of indigenous Tswana goats. *South African Journal of Animal Science* 48(5): 925-934.

Msanga, Y. N., Mwakilembe, P. L. and Sendalo, D. (2012). The indigenous cattle of the Southern Highlands of Tanzania: distinct phenotypic features, performance and uses. *Livestock Research for Rural Development* 24(7).

Nsoso, S. J., Podisi, B., Otsogile, E., Mokhutshwane, B. S. and Ahmadu, B. (2004b). Phenotypic Characterization of Indigenous Tswana Goats and Sheep Breeds in Botswana: Continuous Traits. *Tropical Animal Health and Production* 36(8):789–800.

Nsoso, S. J and Madimabe, M. J. (1999). A review of the sheep industry in Botswana: Promoting the Karakul sheep industry. *South African Journal of Animal Science.* 29(3): 258-262.

Okpeku, M., Yakubu, A., Sunday, P., Ozoje, M. O., Ikeobi, C., Adebambo, O. and Ikhide, I. (2011). Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria. *Acta agriculturae Slovenica*. 98(2). 101-109.

Otoikhian, C. S. O., Otoikhian, A. M., Akporhuarho, O. P., Oyefia, V. E and Isidahomen, C. E. (2008). Body measurement parameters as a function of assessing body weight in goats under on-farm research environment. *African Journal of General Agriculture* 4(3): 135-140.

Rege, J. E. O., Tembely, S., Mukasa-Mugerwa, E., Sovani, S., Anindo, D., Lahlou-Kassi, A.,

Nagda, S. and Baker, R. L. (2002). Effect of breed and season on production and response to infections with gastro-intestinal nematode parasites in sheep in the highlands of Ethiopia. *Livestock Production Science* 78(2):159–174.

Schierenbeck, K. A. (2017). Population-level genetic variation and climate change in a biodiversity hotspot. *Annals of botany* 119(2):215–228.

Shibabaw W. (2012). On-farm Phenotypic Characterization of Hararghe Highland Sheep and Their Production Practices in Eastern Hararghe Zone, Ethiopia. [Thesis]. School of Graduate Studies of Haramaya University, Ethiopia.

Statistics Botswna (2016). Agricultural census stats brief of 2015. Gaborone, Botswana. http://www.statsbots.org.bw/sites/default/files/BotswanaAgricultureCensusReportFinal2015.pdf (accessed 16 February 2020).

Söderquist, L. and F. Hulten, (2006). Normal values for the scrotal circumference in rams of Gotlandic Breed. *Reproduction in Domestic Animals* 41(1): 61-62.

Sölkner, J., Nakimbugwe, H. and Valle, Z. A. (1998). Analysis of determinants for success and failure of village breeding programmes. In: Proceedings of the Sixth World Congress on Genetics Applied to Livestock Production, vol. 25, Armidale, NSW, Australia, 11–16 January 1998, pp. 273–280.

Soma, P., Kotze, A., Grobler, J.P. and Van Wyk, J. B. (2012). South African sheep breeds: Population genetic structure and conservation implications. *Small Ruminant Research* 103(2-3): 112–119.

Song, S., Dey, D. K. and Holsinger, K. E. (2006). Differentiation among populations with migration, mutation and drift: implications for genetic inference. *Evolution* 60(1):1-12.

Sowande, O. S. and Sobola, O. S. (2007). Body measurements of West African dwarf sheep as parameters for estimation of live weight. *Tropical Animal Health Production* 40(6): 433-439.

Tassew, M. (2012). On-Farm Phenotypic Characterization of Native Sheep Types and Their Husbandry Practices in North Wollo Zone of the Amhara Region. An M.Sc. Thesis presented to the School of Graduate Studies of Haramaya University.

Tibbo, M. and Ginbar, T. (2004). Phenotypic characterization of the Bonga sheep in Kaffa zone: Field mission Report. 8p

Tibbo, M., Ayalew, W., Awgichew, K., Ermias, E. and Rege, J. E. O. (2004). On-station characterization of indigenous Menz and Horro sheep breeds in the central highlands of Ethiopia. *Animal Genetic Resources Information* 35:61-74.

Wilson, R. T. and Durkin, J. W. (1984). Age at permanent incisor eruption in indigenous goats and sheep in semi-arid Africa. *Livestock Production Science*. 11(4):451–455.

Woods, J. and Sekhwela, M. B. M. (2012). The Vegetation Resources of Botswana’s Savannas: An Overview. South African Geographical Journal. 85:1, 69-79.

CHAPTER 5

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1. General discussion

In the framework of developing realistic breed improvement programs that will guide the sustainable utilization of indigenous sheep animal genetic resources (AnGR), it is a prerequisite to firstly characterize these AnGR and understand their natural production environment and the context of their utilization. The main objective of this study was therefore to phenotypically characterize indigenous Tswana sheep and the production systems to which they are kept in some selected districts of Southern Botswana; Kgatleng, Kweneng, Southern and South-East districts.

Understanding the purposes for which farmers keep sheep is core if formulation of breeding goals, improvement and conservation programmes that are relevant and specific to a locality (Kogsey *et al*., 2008). Sheep were kept for multifaceted roles for farmers across districts. Amongst the purposes for keeping sheep, the primary purpose of keeping sheep in Kgatleng and Kweneng districts is for cash derived from selling the animals. Southern and South-East district farmers primarily kept sheep for ceremonies (socio-cultural). The use of sheep in generating household income via sales reported in Kgatleng and Kweneng districts is consistent with Kogsey *et al*., (2008) who outlined the importance of livestock in generating income for small ruminant farmers in Kenya amongst other purposes. Superiority in competitive performance of Tswana sheep over its exotic counterparts under tropical conditions was considered the most important trait by Kgatleng, Kweneng and South-East district farmers when selecting rams. On the other hand, selection of rams in the Southern district farmers is mainly based on body size (0.372) and is attributed to their primary purpose for keeping sheep (ceremonial purposes where large bodied animals are preferred) hence the need for well grown, structurally sound and large-bodied animals.

The desire for larger animals that can catch a better selling price/income has also been reported for farmers in Kenya (Zonabend König *et al*., 2015). Castration of rams in Kgatleng, Kweneng and South-East districts was done at 3-6 months while Southern district farmers castrated at a later period of 6-12 months. This similar practice has been reported by Zewdu (2008) who reported an average castration age of 10.8 ± 2.5 months for Adiyo Kaka rams of Ethiopia and Taye *et al*., (2016) who reported an average castration age of 12.09±4.10 months for Doyogena rams in Ethiopia. The late castration age gives the farmer some of the benefit of the increased male hormone growth effect produced in entire males than castrates as entire males grow faster than castrates. This finding is further supported by the trials of Hybu (2004) who reported that carcasses of entire male lambs were up to 1kg heavier than those of castrates of the same age and they also had a lower fat content thus improved meat quality.

In the second study, visual observations of qualitative traits and quantitative traits were made on a total of 665 sheep for phenotypic characterization of indigenous Tswana sheep in the four selected districts of Southern Botswana. There was a variety of coat coloration patterns amongst Tswana sheep across districts with most sheep having plain coat color patterns followed by patchy coat patterns and to a lesser extend spots of different colors (black and brown colors). Most Tswana sheep across districts were white dominated and plain white in color. White dominated suggests that the sheep had other skin colors but most of their skin coat was white. The higher proportions of animals with white dominated coat colour and plain white coat could be a reflection of natural selection for animals manifesting white colour to withstand the hot environment of Botswana. Most Tswana sheep had a characteristic of short fat tail with a straight tail form at the tip pointing downwards. The fat tail character is an adaptive attribute possessed by some South African breeds (Soma *et al*., 2012) as it acts as an energy reserve which helps Tswana sheep genetic resources to adapt and survive during periods of feed fluctuations (Ermias *et al*., 2002). Most indigenous Tswana sheep had no wattles and characterised by horizontal ear form orientation (98.65%). A comparatively high proportion of indigenous Tswana sheep across districts did not have horns and a high proportion of sheep with horns had their horns curving backwards as opposed to straight.

Generally, the number of female sheep increased with age and hence females out-numbered males (rams and castrates) across all age groups except for the 6-11month age group where almost similar numbers were recorded between the two sexes. This is because traditionally, selection of breeding rams is mostly done after 12 months of age after the rams have reached sexual maturity while almost all females are retained for breeding. Rams that have not been selected for breeding are castrated, culled or sold to other farmers who further do selection of the rams to suit their farming needs (Nsoso *et al*., 2004b) hence few males were observed after 12 months while the number of females was high.

The district effect was significant ($P<0.05$) for body weight and most linear body measurements except cannon bone circumference. Several authors reported a significant district effect on body weight and linear body measurements; (Asefa *et al*., 2017; Alemayehu, 2011; Kunene *et al*., 2007). Southern district sheep were the heaviest (38.93±0.55 kg) and Kweneng sheep were the lightest (34.14±0.53 kg). Generally, Tswana sheep were comparable in body weight to Zulu sheep (39.76 kg to 40.26 kg) (Kunene *et al*., 2007) and heavier than several indigenous sheep of Ethiopia (Asaminew *et al*., 2016; Michael *et al*., 2016; Mohammed *et al*., 2017). Tswana sheep are however lighter than Balami and Uda sheep types from South, Middle belt and North West districts of Nigeria (Agaviezor *et al*., 2012).

Generally, Tswana sheep had similar heart girth with Uda sheep of Nigeria (Agaviezor *et al*., 2012) and Hulet eju sheep in Ethiopia (Michael *et al*., 2016). The heart girth of Tswana sheep in the

Southern district was higher than the heart girth of sheep in Wogide, Borena and Legambo districts of Ethiopia (Mohammed *et al*., 2017) and Sinan and Hulet eju sheep of Ethiopia (Michael *et al*., 2016). Southern district Tswana sheep had the longest body length than sheep from other districts while Kweneng district sheep were the shortest. Body length of Tswana sheep in Kgatleng, Kweneng and Southern sheep were similar to those of Gozamen, Sinan and Hulet-eju sheep of Ethiopia (Michael *et al*., 2016) and longer than those of Borena and Legambo sheep of Ethiopia (Mohammed *et al*., 2017). Generally, Tswana sheep across the districts were shorter than Soddo Zuria and Damote Gale of Southern Ethiopia (Asaminew *et al*., 2016). The differences in body weight and other linear body measurements could be as a result of differences in breed structure emanating from the influences of evolutionary forces, nutritional and management practices between districts. The variations in body weight and linear body measurements existing between districts shows diversity which is an opportunity for development of improvement programmes for Tswana sheep (Berhanu and Haile, 2009).

Rams from Kgatleng and Kweneng had similar scrotal circumferences that were significantly higher than those of rams kept in South-East and Southern districts. The significant influence of district on scrotal circumference of Tswana sheep found in the current study is contrary to Mohammed *et al*., (2017) for Wogide, Borena and Legambo rams of Ethiopia and Michael *et al*., (2016) for Gozamen, Sinan and Hulet eju rams of Ethiopia who reported a non-significant influence of district on ram scrotal circumference. A non-significant district influence on scrotal circumference implies that the fertility and breeding ability of the rams in the different districts are the same. Therefore, if selection is to be done, any ram from any district stands an equal chance of being selected for breeding purposes. The scrotal circumference of Southern and South-East rams are similar to that of South African Zulu rams (Kunene *et al*., 2007). This similarity of Tswana sheep to Zulu sheep could mean the two breeds are ecotypes of the same breed, just divided by trans-boundaries. Generally, the scrotal circumference of Tswana rams was higher than that of Borena rams of Ethiopia (Mohammed *et al*., 2017) and Soddo Zuria, Damote Gale and Damote Sore rams of Ethiopia (Asaminew *et al*., 2016). Differences in scrotal circumference between breeds and districts might be due to the fact that testicular size varies with breed, age of an animal and season/time of the year (Söderquist and Hulten, 2006).

There were positive and significant ($P<0.05$) correlations observed between body weight and most LBMs for both males and females. Heart girth had the highest correlation to body weight and accounted for more variability than most LBMs for both males (93%) and females (80%), thus it was used as a sole predictor of body weight. The prediction of body weight for Tswana sheep was based on the regression equations $y= -64.15+1.28x$ in males and $y= -53.47+1.14x$ for females where, x and y are heart girth and body weight respectively.

5.2. Conclusions

Indigenous Tswana sheep are mainly kept by males, single people, and aged 51-60 possessing primary and secondary level of education. Most farmers depend on free grazing as the major feed source with supplementary feeding practiced only during the dry season when feed quality and quantity is compromised and hardly any supplementation is practiced during the wet season. Selection of rams in Kgatleng, Kweneng and South-East was primarily based on competitive superiority of indigenous Tswana rams in terms of survival and reproduction over its exotic counterparts under tropical conditions, whilst in the Southern district ram selection was mainly based on body size. Majority of the farmers had access and used modern medication and hardly no use of ethno-veterinary practices was used. Farmers prefer keeping Tswana rams originating from their own flocks for breeding purposes and prefer castration of males to be done at a later stage of 6-12 months. Most Tswana sheep were characterized by plain coat color pattern with white dominated and plain white colors, short-fat tails with a straight tip, horizontal ear form, no horns and had no wattles. District, sex and age and the age by sex interaction had a significant ($P<0.05$) effect on body weight and most linear body measurements. The body weight of sheep increased gradually as the sheep advancement in age. Tswana males were heavier and superior than females in most linear body measurements. Generally, Tswana sheep from the Southern district showed superiority in some traits of economic importance such as body weight, body length and heart girth over other districts. There were good phenotypic correlations between body weight and most linear body measurements. In the current study, heart girth accounted for most of the variability in body weight than other linear body measurements in both males and females and was used as the sole predictor of body weight. The prediction equation for body weight in Tswana sheep males was $y= -64.15+1.28x$ and for females was $y= -53.47+1.14x$ where, x and y are heart girth and body weight, respectively. .

5.3. Recommendations

1) It is important that the farmers' trait preferences identified in this study be included in development of realistic breeding objectives for Tswana sheep in the production systems.
2) There is also need to improve the productivity of the Tswana sheep populations by estimating genetic parameters of some traits of economic importance for the improvement and implementation of conservation policies and breeding programmes for the animals.
3) Further research to understand the diversity of indigenous Tswana sheep at a molecular level is required.

5.4. References

Alemayehu A (2011). Phenotypic characterization of indigenous sheep types of Dawuro zone and Konta special woreda of SNNPR, Ethiopia. M.Sc. Thesis presented to the School of Graduate Studies of Haramaya University, Dire Dawa, Ethiopia.

Agaviezor, B. O., Peters, S. O., Adefenwa, M. A., Yakubu, A., Adebambo, O. A., Ozoje, M. O., Ikeobi, C. O. N., Wheto, M., Ajayi, O. O., Amusan, S. A., Ekundayo, O. J., Sanni, T. M., Okpeku, M., Onasanya, G. O., De Donato, M., Ilori, B. M., Kizilkaya, K.and Imumorin, I. G. (2012). Morphological and microsatellite DNA diversity of Nigerian indigenous sheep. *Journal of Animal Science and Biotechnology*. 3(1):1-16.

Asaminew, M., Kebede, K. and Mekasha, Y. (2016). On farm phenotypic characterization of indigenous sheep types in Woliata Zone, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare.* 6(11):114-124.

Asefa, B., Abate, T. and Adunga, E. (2017). Phenotypic characterization of indigenous sheep types in Bale Zone, Oromia Regional State, Ethiopia. *Journal of Veterinary Science and Technology* 8(4): 1-7.

Berhanu, B. and Haile, A. (2009). Reproductive performance of traditionally managed sheep in the South Western part of Ethiopia. *Livestock Research for Rural Development* 21 (9).

Ermias, E., Yami, A. and Rege, J. E. O. (2002). Fat deposition in tropical sheep as adaptive attribute to periodic feed fluctuation. *Journal of Animal Breeding and Genetics*. 119:235-246.

Hybu, C.C. (2004). Rearing entire males. Retrieved on 14 April 2021 from www.hccmpw.org.uk/medialibrary/pdf/EN_539_Rearing%20Entire%20Males.pdf

Kogsey, I. S., Rowlands, G. J., van Arendonk, J. A. M. and Baker, R. L. (2008). Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research*. 77:11-24.

Kunene, N. W., Nesamvuni, E. A. and Fossey, A. (2007). Characterization of Zulu (Nguni) sheep using linear body measurements and some environmental factors affecting these measurements. *South African Journal of Animal Science*. 37(1):11–20.

Michael, A., Kefelegn, K. and Yoseph, M. (2016). Phenotypic Characterization of Indigenous Sheep Types In Northern Ethiopia. *Journal of Natural Science Resources*. 6 (15):16-27.

Mohammed, N., Alemayehu, K. and Getachew, T. (2017). On-farm phenotypic characterisation of indigenous sheep population and its cross with Awassi in Selected Districts of South Wollo, Amhara, Ethiopia. *Tropical Drylands* 1(1):1-11.

Nsoso, S. J., Podisi, B., Otsogile, E., Mokhutshwane, B. S. and Ahmadu, B. (2004b). Phenotypic Characterization of Indigenous Tswana Goats and Sheep Breeds in Botswana: Continuous Traits. Tropical Animal Health and Production 36(8): 789–800.

Söderquist, L and Hulten, F. (2006). Normal values for the scrotal circumference in rams of Gotlandic Breed. *Reproduction in Domestic Animals* 41(1): 61-62.

Soma, P., Kotze, A., Grobler, J. P. and Van Wyk, J. B. (2012). South African sheep breeds: Population genetic structure and conservation implications. *Small Ruminant Research* 103(2-3): 112–119.

Taye, M., Yilma, M., Rischkowsky, B., Dessie, T., Okeyo, M., Mekuriaw, G., Haile, A. (2016). Morphological characteristics and linear body measurements of Doyogena sheep in

Doyogena district of SNNPR, Ethiopia. *African Journal of Agricultural Research* 11(48):4873-4885.

Zewdu, E. (2008). Characterization of Bonga and Horro indigenous sheep breeds of smallholders for designing community based breeding strategies in Ethiopia. MSc thesis submitted to the department of animal science, school of graduate studies, Haramaya University .33p.

Zonabend König, E., Mirkena, T., Strandberg, E., Audho, J., Ojango, J., Malmfors, B., Okeyo, A. M., Philipsson, J. (2015). Participatory definition of breeding objectives for sheep breeds under pastoral systems—the case of Red Maasai and Dorper sheep in Kenya. *Tropical Animal Health Production* 48:9–20.

APPENDICES

Appendix A: Least square means ± Standard errors for fixed effects of districts, sex, age group and sex by age interaction on body weight (kg) LBMs (cm) for indigenous Tswana sheep

Effects & levels	BW	BL	HG	WH	RH	SW	EL	RL	SC
	LSM±SE	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**	**LSM±SE**
Overall	35.93±0.55	62.17±0.53	78.31±0.65	64.51±0.51	64.44±0.31	21.79±0.33	11.43±0.12	23.56±0.28	26.66±0.89
R^2	0.59	0.41	0.58	0.40	0.39	0.51	0.16	0.35	0.41
CV	15.28	6.89	5.89	6.88	6.29	10.56	9.75	9.62	10.18
District	*	*	*	*	*	*	*	*	*
Kgatleng	37.41^{a}±0.59	62.56^{ab}±0.62	78.72^{b}±0.78	64.69^{b}±0.52	23.22^{bc}±0.29	22.77^{a}±0.34	12.25^{a}±0.12	23.22^{bc}±0.29	26.09^{ab}±0.76
Kweneng	34.14^{b}±0.53	61.36^{b}±0.57	77.24^{b}±0.72	64.59^{b}±0.48	22.53^{c}±0.27	21.73^{b}±0.32	11.22^{b}±0.12	22.53^{c}±0.27	28.12^{a}±0.79
South-East	34.94^{b}±0.54	62.18^{ab}±0.59	78.06^{b}±0.74	66.28^{a}±0.49	23.72^{b}±0.27	23.11^{a}±0.33	11.17^{bc}±0.12	23.72^{b}±0.27	24.27^{b}±0.95
Southern	38.93^{a}±0.55	63.18^{a}±0.58	81.00^{a}±0.73	65.62^{ab}±0.48	25.56^{a}±0.27	21.79^{b}±0.32	10.89^{c}±0.12	25.56^{a}±0.27	24.50^{b}±1.11
Sex	*	*	*	*	*	*	**NS**	*	-
Male	38.60^{a}±0.53	63.11^{a}±0.60	80.00^{a}±0.72	66.70^{a}±0.49	66.41^{a}±0.48	22.84 ^{a}±032	11.21±0.11	24.04^{a}±0.26	25.85±0.56
Female	33.07^{b}±0.33	60.89^{b}±0.45	77.35^{b}±0.43	63.55^{b}±0.29	63.73^{b}±0.29	20.84^{b}±0.19	11.48±0.07	23.24^{b}±0.16	**NA**
Castrate	37.40^{a}±0.55	62.03^{a}±0.45	78.9^{ab}±0.73	65.64^{a}±0.49	65.06^{a}±0.49	23.37^{a}±0.32	11.45±0.12	23.99^{a}±0.27	**NA**
Age group	*	*	*	*	*	*	*	*	*
0PPI	26.20^{d}±0.53	55.59^{d}±0.45	70.23^{d}±0.49	60.22^{c}±0.47	60.05^{d}±0.47	19.45^{d}±0.24	10.66^{c}±0.12	21.23^{c}±0.24	23.78^{c}±1.01
1PPI	35.31^{c}±0.59	61.62^{c}±0.48	77.70^{c}±0.52	64.34^{b}±0.50	63.87^{c}±0.50	21.23^{c}±0.26	11.15^{b}±0.13	23.79^{b}±0.25	23.86^{c}±1.17
2PPI	39.27^{b}±0.58	63.42^{b}±0.48	80.62^{b}±0.52	65.49^{b}±0.50	65.44^{b}±0.51	22.59^{b}±0.26	11.67^{a}±0.13	23.67^{b}±0.26	26.83^{bc}±1.23
≥3PPI	44.64^{a}±0.52	66.41^{a}±0.42	85.07^{a}±0.45	69.69^{a}±0.44	69.38^{a}±0.44	25.30^{a}±0.23	11.84^{a}±0.11	25.91^{a}±0.22	28.92^{ab}±1.02
Sex by Age	*	*	*	*	*	*	*	*	*
Male 0PPI	28.54^{d}±0.97	58.80^{c}±0.82	72.26^{d}±0.89	61.63^{c}±0.85	62.19^{c}±0.86	20.04^{d}±0.44	10.76^{c}±0.21	21.20^{c}±0.44	23.78±1.01^{b}
Male 1PPI	37.21^{c}±1.09	62.36^{b}±0.93	79.05^{c}±1.01	65.38^{b}±0.37	64.90^{b}±0.97	21.52^{c}±0.50	10.95^{b}±0.24	24.00^{b}±0.49	23.87±1.17^{b}
Male 2PPI	41.70^{b}±1.18	64.03^{b}±0.98	82.03^{b}±1.06	67.53^{b}±1.02	67.00^{b}±1.02	23.00^{b}±0.52	11.42^{a}±0.26	23.94^{b}±0.52	26.83±1.23^{ab}
Male ≥3PPI	46.94^{a}±1.03	67.26^{a}±0.82	86.39^{a}±0.89	72.07^{a}±0.85	71.11^{a}±0.86	26.67^{a}±0.44	11.81^{a}±0.21	26.37^{a}±0.44	28.98±1.02^{a}
Female 0PPI	24.32^{d}±0.76	55.44^{c}±0.66	68.13^{d}±0.71	58.44^{c}±0.69	58.24^{c}±0.69	17.81^{c}±0.36	10.51c±0.17	20.89^{c}±0.35	**NA**
Female 1PPI	32.70^{c}±0.72	61.15^{b}±0.61	75.32^{c}±0.66	62.63^{b}±0.63	62.29^{b}±0.64	20.33^{b}±0.33	11.39^{b}±0.16	22.68^{b}±0.32	**NA**
Female 2PPI	35.66^{b}±0.64	62.03^{b}±0.54	78.32^{b}±0.58	62.75^{b}±0.56	63.10^{b}±0.56	21.12^{b}±0.29	11.82^{a}±0.14	23.34^{a}±0.28	**NA**
Female ≥3PPI	39.59^{a}±0.50	64.93a±0.43	81.72^{a}±0.46	65.96^{a}±0.44	66.44^{a}±0.45	22.24^{a}±0.23	11.83^{a}±0.11	24.32^{a}±0.23	**NA**

Appendix A continued.

Effects & levels	CBC	CBL	NL	RW	HW	HL	TL	TC
	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	7.51±0.52	15.19±0.12	30.38±0.43	15.98±0.20	10.00±0.11	13.15±0.13	33.67±0.38	18.54±0.45
R^2	0.01	0.46	0.47	0.32	0.36	0.50	0.17	0.29
CV	63.70	6.54	9.83	10.89	11.08	8.58	70.70	66.36
District	**NS**	*	*	*	*	*	*	*
Kgatleng	7.81±0.54	15.43^{ab}±0.14	31.06^{b}±0.43	16.79^{a}±0.22	11.11^{a}±0.12	14.04^{a}±0.17	34.92^{ac}±0.86	18.76^{b}±0.48
Kweneng	7.83±0.50	14.91^{c}±0.13	28.73^{c}±0.40	14.89^{c}±0.20	9.55^{c}±0.11	12.94^{bc}±0.15	35.77^{a}±0.78	19.39^{b}±0.45
South-East	7.00±0.51	15.73^{a}±0.14	32.25^{a}±0.41	15.93^{b}±0.21	10.61^{b}±0.12	13.21^{b}±0.16	35.52^{a}±0.69	21.88^{a}±0.43
Southern	7.11±0.50	15.26^{bc}±0.13	30.07^{b}±0.40	16.58^{ab}±0.20	9.24^{c}±0.12	12.76^{c}±0.16	33.25^{bc}±0.75	19.29^{bc}±0.47
Sex	**NS**	*	*	*	*	*	*	*
Male	7.46±0.50	15.67^{a}±0.13	30.77^{a} ±0.40	16.42^{a}±0.20	10.50^{a}±0.11	13.58^{a}±0.15	36.55^{a}±0.44	22.51^{a}±0.40
Female	7.59±0.30	14.91^{b}±0.08	29.98^{b}±0.24	15.76^{b}±0.12	9.70^{c}±0.07	12.9^{b}±0.09	32.55^{c}±0.34	16.27^{c}±0.31
Castrate	7.27±0.51	15.41^{a}±0.14	30.84^{a}±0.40	15.90^{ab}±0.21	10.17^{b}±0.12	13.19^{a}±0.16	35.10^{b}±0.50	20.70^{b}±0.45
Age group	**NS**	*	*	*	*	*	*	*
0PPI	7.24±0.51	14.00^{d}±0.11	26.29^{d}±0.32	14.23^{c}±0.18	8.89^{d}±0.12	11.53^{d}±0.12	30.50^{d}±0.51	17.13^{c}±0.47
1PPI	7.05±0.54	15.02^{c}±0.11	29.44^{c}±0.34	15.71^{b}±0.20	9.79^{c}±0.12	12.76^{c}±0.13	33.81^{c}±0.51	18.79^{b}±0.47
2PPI	7.39±0.54	15.58^{b}±0.11	31.75^{b}±0.34	16.23^{b}±0.20	10.59^{b}±0.13	13.78^{b}±0.13	35.70^{b}±0.52	19.12^{b}±0.47
≥3PPI	7.98±0.47	16.40^{a}±0.09	33.70^{a}±0.29	17.64^{a}±0.17	10.99^{a}±0.11	14.54^{a}±0.11	38.91^{a}±0.52	24.26^{a}±0.41
Sex by Age	**NS**	*	*	*	*	*	*	*
Male 0PPI	6.98±0.92	14.43^{c}±0.19	27.52^{c}±0.57	14.76^{c}±0.34	9.26^{c}±0.21	10.33^{d}±0.11	31.26^{c}±0.79	18.43^{c}±0.72
Male 1PPI	7.21±1.04	15.50^{b}±0.22	29.93^{b}±0.65	16.24^{b}±0.38	10.24^{b}±0.24	13.17^{c}±0.25	35.98^{b}±0.98	20.71^{b}±0.89
Male 2PPI	7.71±1.10	15.74^{b}±0.23	31.63^{b}±0.68	16.21^{b}±0.40	11.13^{a}±0.25	14.11^{b}±0.26	35.58^{b}±0.90	21.48^{b}±0.82
Male ≥3PPI	8.00±0.92	17.06^{a}±0.19	34.19^{a}±0.57	18.11^{a}±0.34	11.59^{a}±0.21	15.28^{a}±0.22	43.40^{a}±0.83	29.40^{a}±0.76
Female 0PPI	7.88±0.74	13.54^{d}±0.15	25.35^{d}±0.46	14.05^{c}±0.27	8.52^{c}±0.17	11.30^{c}±0.17	28.96^{d}±0.74	14.18^{c}±0.72
Female 1PPI	6.83±0.68	14.46^{c}±0.14	28.35^{c}±0.43	15.36^{b}±0.25	9.35^{b}±0.16	12.28^{b}±0.16	31.25^{c}±0.75	16.76^{ab}±0.69
Female 2PPI	7.13±0.59	15.22^{b}±0.12	30.88^{b}±0.37	16.14^{a}±0.22	10.05^{a}±0.14	13.60^{a}±0.14	36.05^{a}±0.71	16.03^{b}±0.65
Female ≥3PPI	8.19±0.49	15.57^{a}±0.10	32.40^{a}±0.30	16.60^{a}±0.17	10.33^{a}±0.11	13.68^{a}±0.11	33.91^{b}±0.52	18.12^{a}±0.47

Column with different superscripts within the specified dentition group are significantly different ($P<0.05$); NS=Non-significant ($P>0.05$); *significant at $P<0.05$; N.A= not available, BW=Body weight, BL= body length, HG=Heart girth, SW=Shoulder width, WH=Wither height, CBC=Cannon bone circumference, CBL=Cannon bone length, NL=Neck length, Rump length, RW=Rump width, RH=Rump height, HW=Head width, HL=Head length, EL=Ear length, TL=Tail length, TC=Tail circumference and SC=Scrotal circumference; 0PPI=No Pair of Permanent Incisors; 1PPI=1 Pair of Permanent incisors; 2PPI= 2 Pairs of Permanent Incisors; ≥ 3PPI= Pair of permanent incisors

Appendix B: Least square means of quantitative traits of indigenous Tswana Rams, Ewes and castrate sheep in four districts of the Southern part of Botswana (means±SD)

Parameter	**Rams**	**Ewes**	**Castrates**
BW (kg)	$38.60^{a}\pm0.53$	$33.07^{b}\pm0.33$	$37.40^{a}\pm0.55$
HW (cm)	10.50 ± 0.11^{a}	9.70 ± 0.07^{c}	10.17 ± 0.12^{b}
HL (cm)	13.58 ± 0.15^{a}	12.9 ± 0.09^{b}	13.19 ± 0.16^{a}
EL (cm)	11.21±0.11	11.48±0.07	11.45±0.12
SW (cm)	$22.84\,^{a}\pm032$	$20.84^{b}\pm0.19$	$23.37^{a}\pm0.32$
NL (cm)	30.77 ±0.40	29.98±0.24	30.84±0.40
CBC (cm)	7.46±0.50	7.59±0.30	7.27±0.51
CBL (cm)	$15.67^{a}\pm0.13$	$14.91^{b}\pm0.08$	$15.41^{a}\pm0.14$
HG (cm)	$80.00^{a}\pm0.72$	$77.35^{b}\pm0.43$	$78.9^{ab}\pm0.73$
BL (cm)	$63.11^{a}\pm0.60$	$60.89^{b}\pm0.45$	$62.03^{a}\pm0.45$
WH (cm)	$66.70^{a}\pm0.49$	$63.55^{b}\pm0.29$	$65.64^{a}\pm0.49$
RL (cm)	$24.04^{a}\pm0.26$	$23.24^{b}\pm0.16$	$23.99^{a}\pm0.27$
RH (cm)	$66.41^{a}\pm0.48$	$63.73^{b}\pm0.29$	$65.06^{a}\pm0.49$
RW (cm)	$16.42^{a}\pm0.20$	$15.76^{b}\pm0.12$	$15.9^{ab}\pm0.21$
TL (cm)	$35.64^{a}\pm0.65$	$33.14^{b}\pm0.56$	$35.81^{a}\pm0.78$
TC (cm)	$22.15^{a}\pm0.59$	$16.55^{b}\pm0.50$	$20.95^{a}\pm0.71$

^{a,b,c} Means across rows between sexes with different superscript letters are significantly (P>0.05) different BW=Body weight, BL= body length, HG=Heart girth, SW=Shoulder width, WH=Wither height, CBC=Cannon bone circumference, CBL=Cannon bone length, NL=Neck length, Rump length, RW=Rump width, RH=Rump height, HW=Head width, HL=Head length, EL=Ear length, TL=Tail length, TC=Tail circumference and SC=Scrotal circumference

Appendix C: SHEEP PRODUCTION IN SOUTHERN BOTSWANA-Questionnaire

The indigenous Tswana sheep in Botswana have a great potential to improve livelihoods of resource-poor farmers by contributing to food security and poverty alleviation. To develop effective and sustainable management plans for AnGR it is therefore of paramount importance to evaluate and clearly understand indigenous Tswana sheep population diversity and trends, their importance to farmers as well as their production characteristics. The success of any genetic improvement and conservation programme thus depends upon the action of livestock keepers who own, utilize and adopt breeds and adapt them to their needs. Therefore, this survey seeks to understand indigenous Tswana sheep production systems, to understand the importance of indigenous Tswana sheep to farmers and also to identify breeding practices and challenges facing indigenous Tswana sheep production in the Southern part of Botswana.

Enumerator's Name ______________________________ **Date of Interview** / / 20

Farmer's Name ______________________________

1. **District** Name ______________________________

2. **Region** Name______________________________

3. **Village** Name______________________________

4. **Crush/ward** Name______________________________

5. **Farm type** Communal ☐ small scale commercial ☐ large scale commercial ☐ *(tick one)*

6. **Land ownership** (*tick one or more)* Own ☐ lease ☐ Other (Specify)___________________

SECTION 1: HOUSEHOLD STRUCTURE (Demographic Data)

1. **Interviewee's Name** ___________________

Position in household
1. Household head ☐
2. Spouse of head ☐
3. Brother ☐
4. Sister ☐
5. Son ☐
6. Daughter ☐

Other (Specify) _________________.

2. **Household head**

Sex of Head Male ☐
Female ☐

Age (yrs.)
≤ 30……………… ☐
31-40…………… ☐
41-50…………… ☐
51-60…………… ☐
61-70…………… ☐
>70……………… ☐
Not known……… ☐

3. **Marital Status** Married ☐ Single ☐

4. **Level of education** Primary ☐ Secondary ☐ Tertiary ☐ None ☐

5. **Tribe** Name ___________________________

6. **Number of people residing in the household**

Males ☐
Females ☐
Children <15 yrs. ☐

7. **Farm size**

	Area		Units (*tick*)
Crops	☐	Acres	☐
Grazing	☐	Hectares	☐
Forest	☐		

Total size ☐
(Other than communal)

8. **Livestock Activity**

Is livestock the major activity in you farm?

Yes ☐ No ☐

9. **Source of income**

(Please tick where applicable in the first column and rank according to importance in the second column, 1, 2 or 3 with 1 being highest)

1. Crops ☐ ☐
2. Livestock and products ☐ ☐
3. Home industries ☐ ☐
4. Wages/salaries ☐ ☐
5. Other (specify)

____

*include the value of non-cash outputs or products e.g. manure, traction etc.

10(a). **Livestock kept**

(Enter numbers in first column)

(Rank according to most important species; 1, 2 or 3 with 1 being most important)

	Numbers	Rank
1.Cattle………………	☐	☐
2.Goats…………………	☐	☐
3.Sheep………………	☐	☐
4.Pigs…………………	☐	☐
5. Chickens………….	☐	☐
6.Donkey……………..	☐	☐
Other (specify)		
7. ________________	☐	☐

11. **Livestock Production Category**

Divide numbers given in question 10 into the following categories

	Meat	Dairy	Multipurpose
1. Cattle	☐	☐	☐
2. Sheep	☐	☐	☐
3. Goats	☐	☐	☐

10(b) **Sheep flock composition**

Enter numbers in boxes)

Adult males ☐ Adult females ☐

Lambs ☐ Weaners ☐

SECTION 2: PRODUCTION SYSTEM

1. Type of production system

1. Intensive/industrial ☐
2. Extensive/pastoral ☐
3. Semi intensive ☐
4. Free range/backyard ☐

Other (specify)

5.________________ ☐

2. Mobidity

1. Sedentary ☐
2. Transhumant ☐
3. Nomadic ☐

Other (specify)

4.______________ ☐

3. Purpose of keeping sheep

(Please tick where applicable in the first column and rank according to purpose in the second column: 1 for primary purpose, 2 for secondary, 3 for third purpose)

	Purpose	Tick	Rank
1.	Meat……………………	☐	☐
2.	Milk……………………	☐	☐
3.	Stud breeding……………	☐	☐
4.	Manure..........................	☐	☐
5.	Skin……………………	☐	☐
6.	Dowry…………………	☐	☐
7.	Mohair…………………	☐	☐
8.	Cashmere………………	☐	☐
9.	Ceremonies……………	☐	☐
10.	Cultural rites……………	☐	☐
11.	Investment……………	☐	☐
12.	Cash from sales………..	☐	☐

Other (specify)

13.________________ ☐ ☐

4. Member(s) of household who own sheep *(Tick one or more)*

- Head ☐
- Spouse ☐
- Head/spouse together ☐
- Sons ☐
- Daughters ☐
- Others* ☐

Specify*________________________

6. Grazing/Feeding

	Dry season	Wet season
1. Herded	☐	☐
2. Paddock	☐	☐
3. Tethered	☐	☐
4. Stall	☐	☐
5. Yard	☐	☐
6. Free grazing	☐	☐

Other (specify)

7.______________ ☐ ☐

5. Household member responsible for sheep activities

(Tick as appropriate; more than one column in a row may be ticked)

	Adults Males	Adults Females	Boys (<15yrs)	Girls (<15yrs)	Hired labour
1. Purchasing sheep …………	☐	☐	☐	☐	☐
2. Selling ……………………	☐	☐	☐	☐	☐
3. Slaughtering………………	☐	☐	☐	☐	☐
4. Herding……………………	☐	☐	☐	☐	☐
5. Breeding decisions……….	☐	☐	☐	☐	☐
6. Milking……………………	☐	☐	☐	☐	☐
7. Making dairy products……	☐	☐	☐	☐	☐
8. Selling dairy products…….	☐	☐	☐	☐	☐
9. Animal health…………….	☐	☐	☐	☐	☐

7. Supplementary Regime

(Tick as appropriate)

	Dry season	Wet season
1. Roughage/crop residue	☐	☐
2. Minerals (Salts)/Vitamins	☐	☐
3. Bought-in feed/concentrates	☐	☐
4. None	☐	☐
Other (specify)		
5.____________________	☐	☐

8. Housing

	Dry Season	Wet season
1. Kraal	☐	☐
2. Stall/shed	☐	☐
3. Yard	☐	☐
4. None	☐	☐
Other (specify)		
5.________________	☐	☐

9. Materials used for housing

(Tick one or more)

1. Untreated wood/bush…… ☐
2. Treated wood…………… ☐
3. Iron sheets……………… ☐
4. Bricks…………………… ☐
5. Mud……………………… ☐
6. Wire……………………… ☐

Other (specify)

7.__________________ ☐
8.__________________ ☐

10. Form of housing

(Tick if present)

1. Roof………………… ☐
2. Solid wall………… ☐
3. Floor
   a. Concrete……. ☐
   b. Wooden…….. ☐
   c. earth……….. ☐

11. How are the sheep watered?

	Dry season	Wet season
1. Animals go to water………..	☐	☐
2. Water is fetched/provided…	☐	☐
3. Both………………………..	☐	☐

12. Source of water

(Tick one or more)

	Dry Season	Wet Season
1. Borehole……………….	☐	☐
2. Dam/ pond…………….	☐	☐
3. River…………………..	☐	☐
4. Water well…………….	☐	☐
5. Spring…………………	☐	☐
6. Municipal/piped……….	☐	☐
Other (specify)		
7.__________________....	☐	☐

13. Distance to the furthest watering point

	Dry Season	Wet Season
1. At household……………….	☐	☐
2. <1km………………………	☐	☐
3. 1-5 km………………………	☐	☐
4. 6-10km………………………	☐	☐
5. >10km……………………...	☐	☐

14. Frequency of watering

	Dry season	Wet Season
1. Freely available …………….	☐	☐
2. Once a day……………………	☐	☐
3 .Twice a day…………………	☐	☐
4. Every other day……..………	☐	☐
5. Once in 3 day………………..	☐	☐
Other (specify) _____________	☐	☐

15. Water quality

(Tick one or more)

	Dry Season	Wet season
1. Good/clear………	☐	☐
2. Muddy…………..	☐	☐
3. Salty…………….	☐	☐
4. Smelly………….	☐	☐

16. Flock management

Are sheep run together with	Yes	No
a. cattle	☐	☐
b. goats	☐	☐

SECTION 3: HEALTH CARE PRACTICE

1. Access to veterinary services *(Tick as appropriate)*

1. Government Vet. ☐
2. Private Vet. ☐
3. Veterinary Drug Supplier ☐
4. Extension ☐
5. None ☐

Other (specify)

6.________________________ ☐

2. Common diseases that occur in the farm

diseases that are seen by farmers in his animals)

If none tick this box ☐

Local name or symptoms of disease *(Rank/list most common first)*	Prevalence of disease			Are animals treated when sick		
	Dry Season	Wet Season	All year round	Yes	No	*(if yes* treatment given if known)*
1.____________	☐	☐	☐	☐	☐	____________
2.____________	☐	☐	☐	☐	☐	____________
3.____________	☐	☐	☐	☐	☐	____________
4.____________	☐	☐	☐	☐	☐	____________
5.____________	☐	☐	☐	☐	☐	____________
6.____________	☐	☐	☐	☐	☐	____________

3. Vaccinations/ preventative measures given

If none tick this box ☐

Local name or symptoms of disease	Done routinely	if yes, specify when	Done when need arises
1.____________	☐	____________	☐
2.____________	☐	____________	☐
3.____________	☐	____________	☐
4.____________	☐	____________	☐
5.____________	☐	____________	☐
6.____________	☐	____________	☐

4. Ectoparasite control

Are there means to control external parasites? Yes ☐ No ☐

If yes, thick appropriately below.

Method used	(Tick)	Done when need arises: Dry season	Done when need arises: Wet season	Done routinely: Dry season	Done routinely: Wet season	if done routinely specify how often: Dry season	if done routinely specify how often: Wet season
1. None……………	☐						
2. Dip………………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
3. Spray……………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
4. Pour-on………..	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
5. Hand dressing…..	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
6. Injectable………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
7. Traditional………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks

If traditional method specify________________________

Other (specify)

4. _______________	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks

5. Internal parasite control

Are there means to control external parasites? Yes ☐ No ☐

Method used	(Tick)	Done when need arises: Dry season	Done when need arises: Wet season	Done routinely: Dry season	Done routinely: Wet season	if done routinely specify how often: Dry season	if done routinely specify how often: Wet season
1. None……………	☐						
2. Drench…………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks
3. Traditional………	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks

If traditional method specify________________________

Other (specify)

5. _______________	☐	☐	☐	☐	☐	every ☐ weeks	every ☐ weeks

SECTION 4: CASTRATION/ENTRIES/EXITS/CULLING

1. Castration

Do you castrate? Yes ☐ No ☐

If yes, mention at what age *(Tick one or more boxes)*

1. < 3 months ☐
2. 3-6 months ☐
3. 6-12 months ☐
4. > 12 months ☐

.

Reasons for castration *(Tick one or more boxes)*

1. Control breeding ☐
2. Better temperament ☐
3. Improve meat quality ☐

Other (specify)

4. ____________________ ☐

2. Number of entries within last 12 months

(For questions 2. and 3. first ask for information on kids and others (i.e. weaners and adults total). Then complete individual columns for weaners and adults if known. Enter X in a box if not known, 0 if answer is none)

	Lambs	Weaners	Adults Males	Adults Females	Total W + A
1. Born	☐				
2. Bought	☐	☐	☐	☐	☐
3. Donate/ gift	☐	☐	☐	☐	☐
4. Exchanged/lent	☐	☐	☐	☐	☐

(Weaners and Adults)

3. Number of exits within the last 12 months

	Lambs	Weaners	Adults Males	Adults Females	Total W + A
1.Died	☐	☐	☐	☐	☐
2. Sold	☐	☐	☐	☐	☐
3. Slaughtered	☐	☐	☐	☐	☐
4. Donated/ gift	☐	☐	☐	☐	☐
5.Exchanged/	☐	☐	☐	☐	☐
6. Stolen/lost	☐	☐	☐	☐	☐

(Weaners and Adults)

4. Sale Outlet *(if sold in last 12 months)*

Were animals sold? Yes ☐ No ☐

If ye; tick one or more boxes

1. Sold at auction………… ☐
2. Sold to butcher………… ☐
3. Sold privately…..………… ☐
4. Sold to abattoir……….. ☐

Other (specify)

5.________________ ☐

5. Reasons for culling/disposal

Ask an open question and tick any answers given in the first half of box, one or more boxes may be ticked. Then rank top three reasons by writing in the second box; 1 for primary reason, 2 for second and 3 for third

	Males		Female	
1. Size………………………	☐	☐	☐	☐
2. Conformation………..….	☐	☐	☐	☐
3. Temperament……………	☐	☐	☐	☐
4. Color…………………..	☐	☐	☐	☐
5. Health…….....................	☐	☐	☐	☐
6. Performance…………….	☐	☐	☐	☐
7. Poor fertility……………….	☐	☐	☐	☐
8. Old age…………………	☐	☐	☐	☐
Other (specify)	☐	☐	☐	☐
9.________________	☐	☐	☐	☐
10________________	☐	☐	☐	☐

SECTION 5: BREEDING

1. Primary reason for keeping ram(s)

Tick one

1. Breeding ☐
2. Socio-cultural ☐

Other (specify)

3.____________________ ☐

2. Reasons for choice of ram(s) for breeding

If breeding is not done proceed to the next page

Ask an open question and tick any reason for choice of ram given in the first column box (one or more box maybe ticked). Then rank top three reasons by writing in the second column of boxes rating; 1 for primary reason for choice, 2 for second and 3 for 3rd reason for choice.

1.Size…………………………… ☐ ☐
2. Colour……………………...………… ☐ ☐
3. Conformation/shape…..………. ☐ ☐
4. Horns…..………..………………… ☐ ☐
5. Temperament……………………… ☐ ☐
6. Performance…………………… ☐ ☐
7. Availability (no choice)…………… ☐ ☐

Other (specify)

8. ________________________ ☐ ☐

2. Mating

Tick one or more boxes

1. Uncontrolled ☐
2. Hand mating ☐
3. Group mating ☐
4.A.I ☐

Other (specify)

5.______________ ☐

4. Prolificacy

Consider the lambs currently in the flock

From how many ewes were the lambs born from? ☐

How many of these ewes had;

Singletons……………… ☐
Twins…………………… ☐
Triplets……..…………… ☐

5. Source and breed(s) of breeding rams in the herd

Breed name(s) *(specify if known-crosses can be included)*

Tick one or more boxes

1. Own ram (self-bred)………… ☐
2. Own ram (bought)………….. ☐
3. Ram donated………………. ☐
4. Ram borrowed……………… ☐
5. Communal area ram………. ☐
6. Other (specify)……………… ☐.

Breed type of ram(s)

Tick

1. Tswana………… ☐
2. Dorper………… ☐
3. Karakul………… ☐
4. Cross….………… ☐
5. Other (specify)…. ☐

________________ ☐

How many of the following sheep breeds do vou have?

Include sheep owned by other members of this household (Total number per each category)

	Male	Female	Castrate
1. Tswana……..			
2.Dorper……..…			
3. Karakul…..….			
4. Crosses……..			
5. Other (specify).			
_______________			

Any taboos used on sheep? *(Tick appropriately)* Yes ☐ No ☐

If yes please describe in detail

…………………………………………………………………………………………

GENERAL COMMENTS