UNIVERSITY OF BOTSWANA

Phenotypic and genetic characterization of indigenous Tswana pigs and their reproductive performance under an intensive management system

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Master of Science in Animal Science

PHENOTYPIC AND GENETIC CHARACTERIZATION OF INDIGENOUS TSWANA PIGS AND THEIR REPRODUCTIVE PERFORMANCE UNDER AN INTENSIVE MANAGEMENT SYSTEM

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

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A thesis presented to the Department of Animal Science and Production in partial fulfilment of the requirements for the degree of Master of Science (MSc) in Animal Science (Animal Breeding and Reproduction).

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DECLARATION

I declare that the thesis hereby submitted by me for the Master of Science degree (Animal Science) at University of Botswana, is my own independent work and has not been previously submitted by me to another University or Faculty for the award of any other degree or diploma. All assistance towards the production of this work and references contained herein have been duly accredited.

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ABSTRACT

The study was carried out to phenotypically characterize indigenous Tswana pigs under intensive management system and to genetically characterizatise Indigenous Tswana pig Population using a panel of 12 microsatellite markers. Phenotypic characterisation of Tswana pigs was carried out on a total of 128 F1 progeny piglets and traits evaluated included body weight, heart girth circumference, pelvic and hock circumference, tail and ear length at birth and thereafter fortnightly until piglets were 3 months of age. There was no significant difference in body weights of piglets at birth between male and females and thereafter up to 3 months of age. There was also no significant difference in body length between males and females from day old up to 98 days of age. For height at withers, males had slightly larger heights than females from day old up to 98 days of age. The pelvic widths of males were greater than those of females from day old up to 42 days of age and thereafter females had higher pelvic widths than their age-matched male counterparts up to 98 days of age. There were no significant sex differences in ear length, hock circumference and tail length from day old up to 98 days of age. In the second study, blood samples were collected from 30 Tswana pigs in the Southern half of the country (Kweneng, Kgatleng and South-East districts) and genomic DNA was extracted for genetic characterisation using a panel of 12 microsatellite markers. A total of 76 alleles were detected in 12 microsatellite markers screened and the allele size range varied from 83-107 bp at locus S0073 to 220-234 bp at marker locus Sw2406. The observed heterozygosity for individual markers ranged from 0.16 (Sw2405) to 0.875 (Sw2465) with average observed heterozygosity across all 12 loci of 0.647. The expected heterozygosity was lower than the observed heterozygosity and ranged from 0.143 (Sw2405) to 0.776 (S0385) with mean expected heterozygosity across all loci of 0.603. There is therefore moderate genetic variation in indigenous Tswana pigs found in the Southern half of Botswana.

Keywords: Tswana pigs, genetic diversity, reproductive performance, intensive system

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TABLE OF CONTENTS

Page

Abstract...... i
Acknowledgement.. ii
Table of contents.. iii
List of figures...vi
List of tables...vii
Acronyms and abbreviations..viii

CHAPTER 1: GENERAL INTRODUCTION..1
1.1 Justification...2
1.2 Objectives of the study..3
1.3 Hypothesis...3
References...4

CHAPTER 2: LITERATURE REVIEW..5
2.1 Breed Description of indigenous Tswana pigs..5
2.2 Overview of Indigenous pig population..6
2.3 Pig Production Systems in Botswana...6
2.4 Growth Performance of Indigenous Pigs..7
2.5 Reproductive Performance of Indigenous Pigs..8
2.5.1 Individual Pig Weight at Birth (kg)...8
2.5.2 Litter Size at Birth..9
2.5.3 Litter Size at Weaning...9
2.5.4 Mortality Rate...10
2.6 Challenges of Pig Production...10
2.7 Opportunities of Indigenous Pig Production..11
2.8 Genetic Characterisation of Indigenous Pigs...11
2.8.1 Observed and Effective number of Alleles..11
2.8.2 Observed and Expected Heterozygosity...12
2.8.3 Polymorphic Information Content..13
2.8.4 Hardy-Weinberg Equilibrium..14
2.8.5 Fixation Index...14
References...15

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CHAPTER 3:

Growth and reproductive performance of indigenous Tswana pigs under intensive management system.

3.1 Abstract....................19
3.2 Introduction....................20
3.3 Materials and Methods....................21
3.3.1 Study Area 21
3.3.2 Experimental Animals....................21
3.3.3 Housing and Management of Breeding Herd....................21
3.3.4 Management of Piglets and Measurement of Parameters....................22
3.3.5 Statistical Analysis....................22
3.4 Results and Discussion....................23
3.4.1 Linear Body measurements....................23
3.4.2 Reproductive Performance of Indigenous Tswana Pigs....................27
3.5 Conclusion....................28
3.6 References....................28

CHAPTER 4:

GENETIC CHARACTERIZATION OF INDIGENOUS TSWANA PIG POPULATION USING MICROSATELLITE MARKERS

4.1 Abstract....................31
4.2 Introduction....................32
4.3 Materials and Methods....................34
4.3.1 Population sampling 34
4.3.2 DNA Extraction....................35
4.3.3 Microsatellite markers amplification and analysis....................36
4.3.4 Statistical Analysis....................37
4.4 Results and Discussions....................37
4.5 Conclusion 43
4.6 Acknowledgements....................43
4.7 References....................44

CHAPTER 5:

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General Discussion..47

5.2 General Conclusion..47

5.3 General Recommendations...50

5.4 References...50

LIST OF FIGURES

4.1 Indigenous Tswana Pigs at Department of Agricultural Research, Sebele...33

LIST OF TABLES

3.1 Body Linear Measurements of *Tswana* Pigs under Intensive System 25

3.2 Body Linear Measurements of *Tswana* Pigs under Intensive System 26

3.3 Body Linear Measurements of *Tswana* Pigs under Intensive System 27

3.4 Reproductive Performance of Indigenous *Tswana* Pigs under Intensive System......27

4.1 Locations where *Tswana* pigs were sampled and number of samples per location....35

4.2 Observed and Effective Number of Alleles..39

4.3 Measures of Genetic Diversity in *Tswana* Pigs..42

ACRONYMS AND ABBREVIATIONS

ARC-API	Agricultural Research Council- Animal Production Institute
BUAN	Botswana University of Agriculture and Natural Resources
BW	Body weight
CRD	Completely Randomized Design
DAR	Department of Agricultural Research
DNA	Deoxyribonucleic acid
FAO	Food and Agricultural Organisation
F_{is}	Fixation Index
g	Grams
GLM	General Linear Model
H_e	Expected Heterozygosity
H_o	Observed Heterozygosity
kg	Kilogramme
L	Litre
m^2	metre squared
PCR	Polymerase chain reaction
PIC	Polymorphic Information Content
SAS	Statistical Analysis System
SD	Standard deviation
°C	Degrees Celsius
%	Percentage

CHAPTER 1

GENERAL INTRODUCTION

Pigs have been described as one of the most prolific and fast growing livestock that can convert feed and food waste to valuable product (Kanengoni *et al.*, 2004). They excel above other red meat animals such as cattle, sheep and goats in converting feed to flesh. They have been recommended as an alternative source of cheap, high quality animal protein that suits escalating human population in Nigeria (Ironkwe and Amefule 2008). Furthermore, pig production has been found to be a short term measure towards alleviating animal protein and calorie deficit, especially where there are no religious edicts preventing the production and consumption of pork (Eusebio,1984).

Significant population of indigenous Tswana pigs is found in Botswana (Lekule *et al.*, 1990). These indigenous pigs are kept by the rural populace under the low- output free range production system. Indigenous pigs in Botswana are normally owned by women (Nsoso *et al.*, 2006). These pigs play multiple roles in small scale farming system such as improving livelihoods, poverty alleviation and the rural economy. Indigenous pigs usually survive in harsh, low input environments and strive under heavy diseases, parasite and nutrients challenges (Chabo *et al.*, 2000).

During the 1980's, indigenous Tswana pigs were found in the southern region of Botswana (Ramotswa, Kgatleng, Kweneng) and surrounding areas while nowadays they are fairly well distributed in the south east of the country in and around Ramotswa village (Nsoso *et al.*, 2006). The farmers who keep indigenous pigs in Botswana have a tendency to keep low numbers to match the herd size with available feed resources. Indigenous Tswana pigs are normally reared under free-range management system and are thus highly susceptible to inbreeding and crossbreeding with exotic breeds. Indigenous Tswana pigs are regarded as inferior to their exotic counterparts in terms of growth, carcass traits and reproductive performance. This comparison is somehow unfair because Tswana pigs are normally raised under the extensive production system while their exotic counterparts are normally raised under intensive management system with better nutrition, housing and health care (Lekule and Kyvsgaard, 2003).

According to Chabo *et al.* (2000) commercial pig production enterprises are distributed in cities and major villages where there is lucrative pork market and adequate infrastructure. There is no commercial pig industry based on the Tswana pig despite the fact that they are available and continue to thrive in the country.

The population of indigenous Tswana pigs has declined drastically in the last three decades and the indigenous Tswana pig is currently listed as an endangered animal genetic resource (Podisi 2001). If deliberate efforts towards conservation are not put in place, this valuable genetic resource with its hardiness, disease resistance and heat tolerance genes might go extinct within the next decades, even before it has been fully characterized. The conservation of indigenous Tswana pigs should be given high priority because it contains valuable genes (disease resistance and heat tolerance genes) for future breed developments and genetic engineering applications to counter the effects of global warming or climate change on pig production and productivity. Rege and Lipner (1992) expressed serious concern that some indigenous animal genetic resources of Africa are endangered and may even be lost before they are described and documented, and the indigenous Tswana pig is a classic example. Research to evaluate the indigenous Tswana pig has been sporadic and inadequate; consequently, the indigenous Tswana pig has not been sufficiently characterized. Information on phenotypic characteristics and production performance of Tswana pigs is still very scarce and there has been no attempt to date at their genetic characterization. Genetic characterization of Tswana pigs by microsatellite markers is important to assess the degree of genetic diversity in the remaining population and the extent of inbreeding and will inform future conservation and management practices.

1.1 Justification

Information on growth, reproductive performance and genetic characterization of Indigenous Tswana pigs is scanty. The phenotypic and genetic characterization and conservation of Tswana pig is necessary to measure their potential productivity, genetic diversity and ensure future food security. Hence, the purpose of the study was to evaluate growth and reproductive performance as well as the genetic diversity of indigenous Tswana pig population found in the Southern part of Botswana.

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1.2 Study objectives

(i) To evaluate growth and reproductive performance of indigenous Tswana pigs kept under an intensive management system.

(ii) To genetically characterize Tswana pigs using a panel of 12 microsatellites.

1.2.2 Specific objectives

(i) To determine the total number of indigenous Tswana piglets born, number born alive and number alive at 60 days of age.

(ii) To determine weekly weights and body dimensions of the indigenous Tswana pigs from day old up to 3 months of age.

(iii)To estimate level of homozygosity or heterozygosity in indigenous Tswana pigs.

(iv)To determine number of alleles per marker in indigenous Tswana pigs.

(v) To estimate inbreeding coefficient of indigenous Tswana pigs.

1.3 Hypothesis

H_O: There are no significant differences in litter size, growth performance and genetic diversity among indigenous Tswana pigs kept under an intensive management system.

H_A: There are significant differences in litter size, growth performance and genetic diversity among indigenous Tswana pigs kept under an intensive management system.

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CHAPTER 2

LITERATURE REVIEW

2.1 Breed Description of Tswana Pigs

Indigenous Tswana pigs are usually black or black with white stripes and have a body of medium stature (Nsoso *et al.*, 2006). Lemus *et.al.* (2003) and Nsoso *et al.* (2006) reported that compared to the exotic breeds indigenous pigs have slower growth rate, small mature body size and small litter size and that it is not suitable for commercial production. In the study by Ncube *et al.* (2003) on indigenous pigs of Zimbabwe, piglets from indigenous pigs were predominantly black in colour, although about one percent of them had white and grey stripes along the length of the body. It was found out that the F_1 crosses of Mukota pigs and Large white were largely white, with black patches over the body, mainly on the ears, eye-lids, nose, fore-head and the loin. The predominantly black pigmentation of indigenous Mukota pigs make them less susceptible to sunburn compared to their imported counterparts. Since many communal areas in Zimbabwe are situated in hot environments, the high temperatures make it difficult to keep white pigs under extensive production conditions (Ncube *et al.*, 2003).

Indigenous breeds of livestock are in danger of extinction due to indiscriminate crossbreeding, the expansion of intensive agriculture and of wildlife reserves and other factors (Geerlings *et al.*, 2002). Modern agriculture relies on a few high performance animal breeds. These breeds grow quickly, are highly productive but rely on good quality feed and constant flow of medicine to keep them healthy (Sanathan and Rollefson 2005). The gene pool of these high performance breeds is however, becoming shallow due to intensive selection, artificial insemination and other breeding technologies which have squeezed most of the diversity from the breeds resulting in herds becoming more uniform (Sanathan and Rollefson 2005). However, this uniformity of animals is risky because a disease outbreak can wipe out entire herds, destroying the country's farm economy and rural communities. Indigenous breeds provide the genetic diversity that modern agriculture needs to ensure stability. They are important building blocks for future pig breeds. Conserving them is very important for communities that keep them and for future breeding. Conservation of livestock breeds is possible only if breeds are first identified and documented and if communities that keep them appreciate their value and fully participate in the conservation efforts (Sanathan and Rollefson 2005).

2.2 Overview of the indigenous pig's population

Currently there is no precise census of indigenous Tswana pig's population in Botswana (Mphinyane, 2012). Indigenous pigs have not been adequately characterized (both phenotypically and genotypically) and it is not even known if they represent a single breed or several distinct breeds. As in most Southern African countries they are usually called by the name of the country of origin or the name of the tribe that keep them (Halimani *et al.*, 2010) hence the name Tswana pig. Baitsile, (1999) raised concern about the decline in numbers of indigenous pigs and pointed out the unreliability in the figures of the population size of Tswana pigs. These animals used to be found roaming freely in the villages of Tlokweng, Kgatleng and Ramotswa. However, they are now seen mostly around Ramotswa (Nsoso *et al.*, 2006) at a very low frequency.

According to Piggery Section Annual Report, (2012) of the Ministry of Agricultural Development and Food Security, there were 12899 pigs in the country of which few were assumed to be Tswana pigs as it showed that commercial farmers preferred exotic breeds (Mphinyane 2012). The Sebele Pig Multiplication Facility in Gaborone area which was mandated to supply weaner pigs and replacement breeding stock (gilts and boars) is not able to cope with the demand and the indigenous Tswana pig was not even included in the multiplication facility. According to Podisi (2001), there is very little reliable information on indigenous Tswana pigs as compared to other indigenous domestic animals such as beef cattle, sheep and goats in Botswana. These therefore calls for more effort to be put into pig production including indigenous pigs of Botswana.

2.3 Pig Production systems in Botswana

Pig production systems in Botswana range from extensive (traditional) to intensive (commercial) production systems. In between, these systems could be found subsistence and semi-intensive production system (Nsoso *et al.*, 2006). The extensive or traditional production system is mainly found in the rural village production units (Devendra and Fuller, 1979). The output of such system is low as the animals are left to roam in the village for left over household wastes. Supplementation is provided occasionally with locally available agro-industrial by-products such as pito mash, maize bran, palm kernel cake (Ahunu *et al.*, 1995). The animals are primarily scavengers, utilizing food scraps thrown away by people around homesteads. However, there are some farmers who buy pig feeds, which are based on bran and provide them with tap water (Nsoso *et al.*, 2004). Pigs raised under the traditional system are susceptible to parasites and diseases and they are also carriers of diseases such as hog cholera (Chimonyo *et.al.*,2005). Similar to all indigenous animals in Botswana, Lekule and Kyvsguard (2003) stated that experiences from Africa show that intensive pig farming is stagnant and the sustainability of the traditional sector is better than that of the intensive sector.

2.4 Growth Performance of Indigenous Pigs

Indigenous pigs were long regarded as unsuitable for intensive commercial breeding because of their slow growth and inadequate meat production. However, many local African domestic animal populations show a well-established adaptation to prevailing environmental and management conditions (Chimonyo *et al.*, 2005). Keonouchanh *et al* (2006) highlighted that of the four indigenous pigs of Lao in Southeast Asia, the Moo chid or Moo Boua is relatively small as compared to others existing in the country. Their body length ranged between 75-92cm while the circumference of the girth ranged between 72-85cm at 5-6months of age. The maximum body weight of boars was between 18-30 kg (Keonouchanh *et, al* 2006).

The second type being Moo Lat was quite bigger than the previous group with body length of 85-100cm, while the circumference of the heart girth ranged between 84-102cm and the height ranged between 51-70cm while the maximum body weight of boars ranged between 30-50kg. The Moo Nonghad which was the third type is quite big with the body length of 100-105cm, the girth circumference of 115-130cm and the height of 55-76cm while the maximum weight of boars ranged between 60-80kg. Moo Deng or Moo Berk which was the fourth type of indigenous group of Lao PDR is the biggest of all existing local pigs with the body length of 88-120cm, circumference of the girth of 84-116 cm and body height of 60-70cm with maximum body weight of boars being similar to that of sows at 65-90 kg (Keonouchanh *et al* 2006). In Zimbabwe, the Mukota pigs were reported to reach the weights of 35-40 kg at slaughter ages of five to six months (Chimonyo *et.al.*, 2005).

To improve growth rate in indigenous pigs, crossbreeding has been promoted (Balogun 1981) as quoted Ironkwe and Amefule (2008). Crossbreeding of the indigenous pig with the highly productive exotic breeds usually results in heavier weaners and faster growth of fattening stock when compared with their purebred indigenous counterparts. Usually indigenous pigs have carcasses that have more fat than their exotic counterparts (Chimonyo *et. al.*, 2005). If consumer demand for pork from these pigs is to increase, then leaner indigenous pigs will have to be produced. Okeudu *et al.* (2007) compared the growth performance of indigenous and exotic pigs on restricted feed intake and found that exotic pigs had leaner carcasses and faster growth rates but lower feed efficiency than indigenous pigs. In western Samoa, Udo (1982) simulated three different systems of management, namely village (extensive), semi-commercial (semi-intensive) and commercial levels and compared the post weaning performance of the Large White breed, indigenous Samoan pig and crosses between them. Under the simulated village management level, crossbreds grew significantly faster and had significantly higher dressing percentage than Large White and indigenous pigs. In contrast to the study of Okeudu *et al.* (2007), there were no significant differences in back fat thickness but carcasses of local pigs were significantly shorter than those of Large White.

2.5 Reproductive Performance of Indigenous Pigs

Reproductive performance of pigs is influenced by complex interplay of environmental factors and physiological processes. In the tropics, climate is the most important environmental factor influencing reproductive performance. Reproductive performance is reflected by litter size and weight at birth and at weaning. Several studies have evaluated the performance of indigenous pig breeds, purebred, exotic breeds and various crosses among them under tropical conditions (Chimonyo *et al* 2010).

2.5.1 Individual pig weight at birth(kg)

Individual pig weight at birth refers to the weight of each piglet after furrowing and recorded independently from others. In the Desi pigs of India, the individual pig weight at birth varied from 0.4-0.9 kg (Boro *et al.*, 2016). Boro *et al.* (2016) further recorded individual pig weights at birth in Sikkim local pig of 0.49 kg, 0.86 kg in Mizoran pig, 0.86 kg in Khasi local pig, 0.96 kg in Ghungroo pig and 0.64 kg in Niang megha pig. Keonouchanh (2016) reported individual mean birth weights of 0.65 kg and 1.07kg in the Thai native pig and Meishan pig, respectively, with weights of 1.12 kg and 1.97kg at 7 days and 2.20 to 4.56 kg at 21 days of age, respectively.

2.5.2 Litter size at birth

Litter size at birth refers to the total number of piglets born to each individual sow in a farrowing (Chusi *et al.*, 2016). In a study on the Reproductive attributes of local pig (Votho) of Nagaland, India from the three districts of Kohima, Peren and Phek, Chusi *et, al* (2016) recorded litter sizes of 6.20 in Kohima district, 6.0 in Peren and 6.06 in Phek with the overall mean of 6.28. For the Desi pig of India, the litter size at birth varied from 4-10 while for the Ghungroo it was higher at 8.7 (Boro *et al.*, 2016). Borkotoky *et al*, (2014), also on the Naga local pigs from three different villages of Phek district reported mean litter size at birth of 5.80.

In Sri Lanka, Goonewardene *et al.* (1984) compared pre weaning traits of indigenous pigs, pure-breed Large White and indigenous × Large White crosses and found that the Large White was significantly better than the indigenous pig in litter sizes, litter weight at birth, birth weight, weaning weight and average daily gain. However, there were no significant differences in weaning weight and average daily gain between the indigenous breed and the Large White-sired crossbred (Goonewardene *et al.* 1984) The litter size reported by Goonewardene *et al.* (1984), of 6.44 on Sri-Lankan village pigs was slightly higher than that reported by Adebambo (1986) for the Nigerian indigenous pig which averaged 6.38 as compared to that of large white, which was 10.60. Subalini *et al*, (2010) also reported average litter size of 6.44 in local pigs of Sri-Lanka.

In India, the Mali pig in Tripura recorded mean litter size at birth of 8.6 (Dandapat *et al.*, 2010) while Mong Cai as the major local breed of north Vietnam with medium size and high fertility had mean litter size at birth of approximately 12 (Thuy *et al.*, 2006). Chimonyo *et al.* (2010) also found that the Mukota pigs of Zimbabwe's litter size (7.9) compared favourably with those reported for South Africa (7.2), Nigeria (6.5) and Ghana (6.3). Ncube *et al.* (2003) also reported higher litter size at birth, number born alive and number of weaned piglets in crossbred than in purebred indigenous Mukota pigs of Zimbabwe.

2.5.3 Litter size at weaning

The average weaning period of indigenous piglet range from 28-60 days under different management conditions and in some village pigs, no weaning period is given to allow for natural weaning (Boro *et al.*, 2016). Natural weaning in desi pig may range from 4-6 months. Litter size at weaning refers to the total number of piglets weaned after completion of 8 weeks or 60 days of age. Chusi *et al.* (2016) reported litter size at weaning (8 weeks of age) of 5.40 (Kohima District), 5.20 (Peren) and 5.00 for Phek district with the overall men litter size at weaning of 5.20 in the local Votho pig of Nagaland, India. Boro *et al*, (2016) recorded litter size at weaning on different local breeds ranging from 2.79-9.5 on the Sikkimese local pig and Bangladesh desi pig. Dandapat *et al.* (2010) reported average litter size at weaning (60 days) of 7.5 in Mali pigs in India.

2.5.4 Mortality rate

Pre-weaning percent mortality rate refers to the total number of piglets that died from birth until weaning divided by the total number of piglets born multiplied by one hundred (Chusi *et al.*, 2016). Chusi *et al.* (2010) reported pre-weaning percentage mortality of 0.46, 0.93 and 0.73 in the local Votho pigs of Nagaland, India, in Kohima, Peren and Phek districts, respectively, with the overall pre-weaning percent mortality of 0.70 % across the three districts.

Dandapat *et al.* (2010) reported pre-weaning percent mortality of 3.66 % in the Mali pig in Tripura, India while Chabo *et al.* (2000) reported pre-weaning percent mortality of 35% in Large white pigs in Botswana.

2.6 Challenges of pig production

Inadequate feeding is a major limiting factor for indigenous pig production in tropical Africa. Low levels of management play a major role in declining pig numbers in Botswana. Nsoso *et al.* (2006) pointed out that for most indigenous pigs there was no housing provided, no records kept and most farmers lack information on pig diseases. The majority of farmers do not seek any professional advice on pig management and production systems. The disease outbreaks like the Foot and Mouth at Matsiloje village in the northern Botswana and the collapsing of youth projects due to lack of slaughter facilities are some of the challenges facing pig production in Botswana (Mphinyane, 2012).

High feed prices have been identified as amongst the obstacles to the pig industry in Botswana (Moreki and Montsho, 2011). Currently the country is importing all pig feeds from the neighbouring South Africa and the few feed producing companies charge high fees due to lack of competition. Unavailability of breeding stock, trans-boundary diseases and inadequate extension services have been highlighted as challenges of the local pig industry. Chimonyo *et al.* (2005) highlighted the promotion of exotic breeds in poor communities as one of the reasons why poor households remains poor since these exotic breeds demand high maintenance and sophisticated levels of management which are difficult to maintain by small farmers. Advances in technologies like artificial insemination have speeded international movements of germplasm thus shifting the attention from local pigs to more specialized exotic breeds and the result is genetic erosion of local pigs. In some countries, the keeping of indigenous pig breeds is regarded as being backward. Despite this challenges opportunities exist to make commercial pig production based on indigenous breeds viable in Africa.

2.7 Opportunities of Indigenous Pig Production

In rural communities, indigenous pigs play multiple functions; they provide disposable income during periods of food shortages; pigs are a means to generate and accumulate capital and like other domesticated livestock species, pigs are inflation proof. Pigs are also used in diversifying the economy and act as a buffer to crop production losses. Pigs will utilize resources that have few alternative uses such as agricultural by products, (Chimonyo *et. al.*, 2005). Moreki and Mphinyane (2011) estimated local pork production at 29.1% and imports at 70.9% thus showing the need to increase our production level. Local Enterprise Authority (LEA) (2009) identified pig industry as one of the major breakthrough areas in an effort to diversify the economy away from diamonds in Botswana. The government of Botswana provides support to big commercial farmers through Citizen Entrepreneurship Development Agency (CEDA), Department of Youth Empowerment Sports and Culture and Local Enterprise Authority (LEA). LEA provides training, mentoring and coaching services to farmers at subsidized prices to fully equip aspiring pig farmers with knowledge and skills. On the other hand, CEDA finances young farmers at subsidized rates under Young Farmers Fund and also provides mentoring and coaching services.

2.8 Genetic Characterisation of Indigenous Pigs

2.8.1 Observed and effective number of alleles

The status of the genetic diversity in Southern African indigenous pigs and commercial pig populations is unknown (Swart *et. al.*, 2010). In the study by Kim *et al.* (2005) on the Korean and Chinese breeds, the mean number of alleles was 11.6 with a range of 6 to 17 while in the Pampa-Rocha pig of Uruguay the MNA was 5.72 with a range of 2 to 10 (Montenegro *et.al.*, 2015). The Criollo pigs of the Americas recorded the mean number of alleles of 6.25 and the mean effective number of alleles was 3.33 (Revidatti *et.al,*.2014). In the Chinese pig population, a total of 496 alleles were found at the 20 studied loci across the eleven breeds with a mean number of alleles of 24.8 (Li et al., 2004). In the study by Fang *et al.* (2009) 19 microsatellite loci were genotyped in 10 Chinese village populations including 817 individuals to investigate their genetic diversity and the effective number of alleles (n_e) ranged from 5.16 in the Long Wang population and 6.83 in the Liang Tang population while the MNA ranged between 10.06 in Long Wang population and 17.13 in the Liang Tang populations.

In the Andaman Desi pig of islands of India, the mean number of observed alleles (MNA) and mean number of effective alleles (n_e) were 7.04 ±0.37 and 5.09 ±0.20, respectively (De *et al.*, 2013). Cho *et al.* (2014) reported a total of 62 alleles in four pig breeds (Duroc, Yorkshire, Philippine native pig and Berkshire) and the mean number of alleles ranged between 3.30 in Philippine native pig and 4.80 in the Yorkshire. In a comparative study between Vietnamese and European breeds using 20 microsatellite marker, Thuy *et al.* (2006) reported the mean number of alleles of 3.9 in Meishan pig and 9.3 in Meo pig. The mean number of alleles per marker ranged between 8.1 and 9.3 in Vietnamese breeds sampled from small holder farms while in breeds with European background the mean number of alleles ranged between 4.3 and 4.8 while an even lower mean numbers of alleles per marker between 3.9 and 5.4 were observed from breeds which were kept in stations or included in a commercial breeding programs. In the Southern African domestic pigs Swart *et al.* (2010) found the mean number of alleles per marker of 3.93, 8.45, 6.18 and 5.97 n the Namibian, Mozambican, Kolbroek (RSA) and Kune-Kune (RSA) indigenous breeds, respectively.

2.8.2 Observed and expected heterozygosity

Li *et al.* (2004) stated that for markers to be useful in measuring genetic variation, they should have an average expected heterozygosity (H_e) of between 0.3 and 0.8 in the population. The mean observed (H_o) and expected heterozygosity (H_e) in 10 local Chinese population were 0.46 and 0.66, respectively, (Li *et. al.*, 2004). In the same study, it was found out that although the markers were suitable for measuring genetic variation, the observed mean heterozygosity was lower than the expected mean heterozygosity in all populations. Kim *et al.* (2005) studied Korean, Chinese and European pig breeds and found that expected heterozygosity ranged between 0.494 (Korean native pig) and 0.703 (Min pig of china) while the observed heterozygosity ranged between 0.497 (Korean native pig) and 0.735 (Min pig of China) in the same pig breeds. The overall mean expected and observed heterozygosity were 0.613 and 0.580 for all populations. In the study of Southern Africa pig breeds by Swart *et al.* (2010) the expected heterozygosity was higher in established South Africa Landrace and Large White breeds at 0.580 and 0.636, respectively, compared to that of Duroc at 0.531. In the indigenous breeds the highest heterozygosity levels were found in the Mozambican and South African breeds at 0.692 and 0.634, respectively, while the Namibian indigenous pigs had the lowest heterozygosity value of 0.531. The observed heterozygosity was however lower than the expected heterozygosity in all the studied pig breeds and the observed heterozygosity values were 0.522 for South African Landrace, 0.584 for Large White, 0.504 for Duroc, 0.518 for Namibian breeds, 0.609 for Mozambique breeds, 0.537 for Kolbroek and 0.508 for Kune-Kune (Swart *et. al.*, 2010).

De *et al.* (2013) found the mean expected heterozygosity of 0.622 and the mean observed heterozygosity (H_o) of 0.567 in Criollo pigs while in the Philippine native pigs the (H_e) and (H_o) were 0.290 and 0.403, respectively, (Cho *et al.*, 2014). In the Pampa Rocha pigs of Uruguay, the mean expected heterozygosity was 0.603 while the mean observed heterozygosity was 0.583 (Montenegro *et. al.*, 2015). In the study by Fang *et al* (2009) in 10 Chinese village populations which included 817 individuals the average heterozygosity was 0.806±0.02 for the Long Wang pig population while the highest heterozygosity of 0.833±0.02 was reported in the Shan Dong population.

2.8.3 Polymorphic Information Content

Polymorphic information content (PIC) is a parameter for indicating genetic variation and for measurement of markers informativeness in genetic studies (Cho *et. al.*, 2014). The PIC can vary from 0 to 1 with values closer to 1 indicating a greater level of polymorphism or variation and the markers usefulness in genetic studies. Montenegro *et al.* (2015) stated that markers with PIC values greater than 0.5 were highly informative, those with PIC values between 0.25 and 0.50 were moderately informative while those with values less than 0.25 were uninformative. Using 10 microsatellites in four porcine breeds Cho *et al.* (2014) found that all the 10 markers had PIC values greater than 0.25. Six markers S0225, SW951, S0155, S0026, SW72 and SW787 had PIC values of 0.26, 0.28, 0.44, 0.41,0.47 and 0.49 respectively indicating that they were moderately informative. The remaining four had PIC values of 0.50 (SW936), 0.53 (SW787), 0.57(SW632) and 0.61(S0005). In the Andaman Desi indigenous pigs of India, the mean PIC values for 23 FAO recommended markers was 0.74 ±0.01 indicating that all the markers were highly informative and useful for genetic variation studies (De *et. al.*, 2013). The mean PIC value of the 25 microsatellite markers typed in Pampa Rocha pigs was 0.563 with 17 being highly informative (PIC > 0.5), seven being moderately informative (PIC between 0.25 and 0.5) and only one was uninformative (S0386. PIC less than 0.25) (Montenegro et. al., 2015). Melendez *et al.* (2014) reported mean PIC value of 0.525 on the domestic pig of Colombia using 20 microsatellite markers while Li *et al* (2004) reported mean PIC values of 0.53 in Jinhua breed and 0.74 in Hainan Spotted pig breeds of China using a panel of 20 microsatellite markers.

2.8.4 Hardy-Weinberg Equilibrium

When a population is in a Hardy-Weinberg Equilibrium (HWE) for a locus it means there is random mating, no selection pressure, no mutation, no gene flow and that the population is large enough to avoid effects of genetic drift (Jon-Barker's curriculum unit). When the p-value >0.05 in a marker it means that the marker is in Hardy-Weinberg equilibrium and when it is less than 0.05 it means the marker is not in Hardy-Weinberg equilibrium. In the study by Melendez *et al.* (2013) in the domestic pig of Cerete-Colombia using 20 microsatellite markers, seventeen of the 20 markers were found to be in the Hardy-Weinberg equilibrium. This shows that mating in the population occurred randomly with respect to the 17 loci while non-random mating occurred with respect to the other 3 loci possibly due to selection or linkage disequilibrium with loci under either natural or artificial selection.

2.8.5 Fixation Index

According to Groom *et al.* (2006) Fixation Index (F_{is}) or F-statistic describe how genetic diversity is partitioned in a population. F_{is} values determine whether or not subpopulations have fewer or more heterozygous individuals than expected. If the markers have a positive sign it indicates an excess of homozygotes while a negative sign indicates excess of heterozygotes (Montenegro *et. al.*, 2015). Ayazanga *et al*, (2016) studied Ashanti black pig of Ghana and found that the Fixation index ranged between -0.040 at locus S0178 and 0.610 at locus S0090 and Sw1067 with the overall mean inbreeding coefficient of 0.410.

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CHAPTER 3

Growth and Reproductive Performance of Indigenous Tswana Pigs under Intensive Management System

3.1 Abstract

The study was carried out to evaluate reproductive and growth performance of Tswana pigs' females from day old up to 42 days of age and thereafter females had slightly higher pelvic widths than their age-matched male counterparts up to 3 months of age. There was no significant sex differences in ear length, hock under intensive management system. Reproductive performance of Tswana pigs was evaluated on a total of 10 sows at first and second parity. Litter size and litter weight at birth and litter size and litter weight at weaning were comparatively higher at second than at first parity in Tswana pigs. However pre-weaning piglet mortality was comparatively higher at first than at second parity (11.53% vs. 5.41%). Growth performance was evaluated on a total of 128 piglets. Growth parameters evaluated included body weight, heart girth circumference, pelvic and hock circumference, tail and ear length at day old and thereafter fortnightly until piglets were 3 months of age. There was no significant sex difference in body weights of piglets from day old up to 3 months of age. There were also no significant differences in body length between males and females from day old up to 3 months of age. For height at withers, males had slightly larger but non-significant height at withers than females from day old up to 3 months of age. The pelvic widths of males were slightly greater than those of circumference and tail length from day old up to 98 days of age.

Key words: Tswana pigs, growth performance, reproductive performance, intensive management

3.2 INTRODUCTION

In Southern Africa, a significant population of indigenous pigs is found in several areas of Mozambique, South Africa, Malawi, Namibia, Botswana, Zambia and Zimbabwe (Lekule *et al.*, 1990 as cited by Chimonyo *et. al.*, 2006). Indigenous pigs of Southern Africa are kept by the rural populace under the low-input, low-output free range production system and play multiple roles in small scale farming systems such as improving livelihoods, poverty alleviation and the rural economy. Farmers who own indigenous pigs use them mainly for subsistence (provision of food at household level) and sale. Indigenous pigs may also function as savings and insurance in areas where banks and insurance companies are inaccessible or non-existent (FAO, 2007). Indigenous pigs are adapted to the local, usually harsh, environmental conditions in which they have been kept over centuries. Notable attributes of indigenous pigs include disease resistance, high fertility, parasite and heat tolerance, low protein requirements, ability to utilize course fibre rations and strong feet which make them suitable for free range low-intensity management systems affordable to the rural poor (Gandini and Oldenbroaek, 1999; Lekule and Kyvsgaard, 2003).

The indigenous Tswana pig is usually black or black with white stripes and have a body of medium stature (Nsoso *et al.*, 2006). In the 1980s indigenous Tswana pigs were fairly well distributed in the Kgatleng, Kweneng and South-East districts of Botswana but now the remaining Tswana pigs are mainly confined to the South-East district of Botswana in a village called Ramotswa and the surrounding villages (Nsoso *et al.*, 2006). Tswana pigs are mainly raised under the traditional free range system characterized by poor management, absence or minimal health care and are mainly scavengers utilizing food scraps around homesteads and supplementation is usually with kitchen refuse or agricultural waste products.

Indigenous Tswana pigs are regarded as inferior to their exotic counterparts in terms of growth, carcass traits and reproductive performance, a somewhat unfair comparison because of the differences in the production systems subjected to indigenous pigs (traditional extensive production system) and exotic pigs (Commercial intensive production system). Resource-poor farmers in rural areas view genetic improvement of indigenous Tswana pigs as synonymous to crossbreeding, grading up and possible breed replacement with exotic breeds. Such practices coupled with undeveloped markets for indigenous Tswana pigs and lack of a clear policy on the conservation of indigenous animal genetic resources in the country is leading to the disappearance of indigenous Tswana pigs. The population of indigenous Tswana pigs has declined drastically in the last three decades and the indigenous Tswana pig is currently listed as an endangered animal genetic resource, even before it has been fully characterized. There are no reports on genetic improvement of Tswana pigs and research to evaluate the indigenous Tswana pig has been sporadic and inadequate; consequently, the indigenous Tswana pig has not been sufficiently characterized. The purpose of this study was therefore to evaluate reproductive and growth performance of Tswana pigs under intensive management system.

3.3 MATERIALS AND METHODS

3.3.1 Study Area

The study was done at Botswana University of Agriculture and Natural Resources (BUAN) piggery, Content Farm, Sebele 24.588702^0 S, and 25.942040^0 E. The study was carried out from June 2015 to December 2016 and during the study the environmental temperatures ranged between 15.6^{0c} to 38.2^{0c} and averaged 31^{0c}.

3.3.2 Experimental Animals

A total of 12 indigenous sows aged between 6-8 months of age were borrowed from farmers in Southeast (n=3 from Ramotswa, n=3 from Taung and n=3 from Metsimaswaane) and Kgatleng District (n=3 from Modipane). Two boars were loaned from Department of Agricultural Research in the Ministry of Agricultural Development and Food Security, Botswana for breeding purposes and together with the 12 females served as the foundation stock.

3.3.3 Housing and Management of the Breeding Herd

Upon arrival at BUAN piggery, all the pigs were individually identified using ear tags and then dewormed and dipped to control internal and external parasites, respectively. The indigenous Tswana sows were housed in two separate pens in groups of six measuring 6m × 4 m for the first two months of the study while the boars were housed separately in their own pen. The pigs were acclimatized to intensive management by washing and feeding twice a day and were fed 2kg of dry sow feed at 10 am and 1600 pm. After two months' acclimatization period, the pigs were put into individual pens measuring 2m × 4 m and monitored for signs of heat in the morning and afternoon. At signs of heat, the boar was put into the sow's pen for 2-3 days for breeding purposes and closely monitored during mating to avoid extortion of the penis of the boar. At furrowing, the following traits of sow productivity were recorded for individual sows at first parity; total number of piglets born, number born alive, number born dead, individual piglet weight at farrowing, litter size at 21 days, individual piglet weight ay 60 days and number alive at 60 days and there after the sows were fed lactating sow diet until weaning of piglets at 3 months of age. After weaning of piglets, the sows were housed together for 1.5 months before rebreeding and measurement of sow productivity parameters at the second parity.

3.3.4 Management of Piglets and Measurement of Parameters

At farrowing, piglets were individually identified using ear tags, weighed and given 1ml of iron injection on the neck muscle. The piglets suckled from their lactating sows and were supplemented with creep feed from 2 weeks to 60 days of age (weaning age). After weaning at 8 weeks of age, the piglets were fed commercial pig grower diet until end of the study at 98 days of age. Phenotypic characterization and growth performance were evaluated on a total of 128 individuals comprising 54 first parity piglets and 74 second parity piglets and each litter served as a replicate. There were therefore 12 replications in each parity with unequal number of sampling units per replicate due to the sow's differences in litter size. A total of 70 males and 58 females participated in the phenotypic characterisation and growth performance study. Phenotypic characterisation and growth performance involved measurement of body weight, body length, heart girth circumference, pelvic and hock circumference, tail and ear length for individual piglets at birth and thereafter fortnightly until piglets were 98 days of age.

3.3.5 Statistical Analysis

The experiment was set up as a completely randomised design and growth data were analysed using the Procedure General Linear Models of Statistical Analysis System (SAS) version 9.2.1 (SAS, 2002-2008). The model included fixed effects of sex (male and female). Results are presented as least square means ±standard error and means separation were by paired t-test with Scheffe's adjustment to account for unequal number of sampling units per replication and unequal number of individuals between the sexes. The differences between least square means were declared significantly different at $P \leq 0.05$. The statistical model used was;

$Y_{ij} = \mu + Sex_i + \varepsilon_{ij}$

Where;

Y_{ij} =observation of individual

μ=population mean

Sex = (male, female)

ε_{ij} = random error

3.4 RESULTS AND DISCUSSION

3.4.1 Linear Body measurements

There were no significant differences ($P<0.05$) in body weight between male and female Tswana piglets from day old to 98 days of age (Table 3.1). The mean weights for the males and females at birth were 1.01 ±0.06 kg and 0.98±0.08 kg, respectively, with the overall mean of 0.99 ±0.07. The birth weight of indigenous Tswana pig is similar to that of Mexican native pig and Nigerian indigenous pig with average birth weight of 0.97 and 1.02kg, respectively (Lemus *et. al.*, 2003; Ate and Oyedipe, 2011). The birth weight of indigenous Tswana pig is also similar to that of the Meishan pig which had average birth weight of 1.07 kg but is higher than that of the Thai native pig with average birth weight of 0.65 kg (Keonouchanh, 2016). Average birth weight of indigenous Tswana pig is however lower than that of the Assam indigenous pig with average birth weight of 3.25kg (Ate and Oyedipe, 2011). The average body weight of indigenous Tswana pigs at 14 days of age (2.88kg) is higher than that of the Thai native pig with average body weight at 14 days of age of 1.61kg but is lower than that of the Meishan pig at the same age with average body weight of 3.74kg (Keonouchanh, 2016). The average body weight of indigenous Tswana pigs at 98 days of age (21.87kg) is similar to that of the Assam indigenous pig of Ghana at similar age (Ate and Oyedipe, 2011). Similar body weights between male and female indigenous Tswana pigs at all ages from day old to 98 days of age is contrary to Egerszegi (2003) who reported significantly higher body weight in male than female pigs in three Mangalica breeds or indigenous breeds of Hungary at 3 years of age. The discrepancy between the two studies could be due to the differences in the ages of the pigs when body weights were measured. In the current study, body weights were measured before attainment of sexual maturity while in Egerszegi's (2003) study body weights were taken after attainment sexual maturity.

There were no significant sexual differences in body length at all ages from day old to 98 days of age in indigenous Tswana pigs (Table 3.1). Similar body lengths between male and female indigenous Tswana pigs is consistent with Egerszegi (2003) who reported similar body lengths of 97cm and 96cm in male and female Blond Mangalica pigs, respectively, and body lengths of 98 and 95cm in male and female Swallow belly indigenous pigs of Hungary, respectively, at 2-3 years of age. Similar body lengths between male and female indigenous Tswana pigs is however contrary to McManus *et al.* (2010) who found significantly higher body length in male than female pigs (115.03 vs. 109.36cm) in naturalized swine breeds in Brazil, Uruguay and Colombia.

There were no significant sexual differences in height at withers in indigenous Tswana pigs at all ages from day old to 98 days of age although males had slightly higher height at withers at all ages than their female counterparts (Table 3.1). Similar height at withers between male and female indigenous Tswana pigs is consistent with Dandapat *et al.* (2010) who also reported slightly higher but non-significant deference in height at withers between sows and boars of Mali pigs in Tripua, India with average height at withers of 65.4 and 65.8cm in sows and boars, respectively. Alenyorege and Opoku (2015) also reported no sex difference in height at withers in 2-3 months old weaner pigs of the Ashanti Black pig of Ghana (30.7cm and 31.6cm in male and female weaner pigs, respectively). Subalini *et al.* (2010) reported similar heart at withers of 48.59 and 50.77cm in adult male and female village pigs of Sri Lanka, respectively.

There were no significant differences in heart girth between male and female indigenous Tswana pigs from day old to 98 days of age. Similar heart girth between male and females indigenous Tswana pigs is consistent with Subalini *et al.* (2010) who found heart girth of 75.14 and 73.66cm in male and female village pigs of Sri Lanka, respectively and Borkotoky *et al.* (2014) who reported heart girths of 58.96 and 65.70cm in male and female Naga pigs of Nagaland, India, respectively. In Tripura India, Dandapat *et, al* (2010) reported the same heart girth of 120.0cm in both male and female Mali pigs. Contrary to the current findings, Alenyorege and Opoku (2015) reported significantly higher heart girth in female than male

(35.2 vs. 29.7cm) Ashanti Black pig weaners aged 2-3 months of age under intensive management system.

There were no significant differences in ear length, hock circumference and tail length between males and females at all ages from day old to 98 days of age except for ear length at 42 days of age (Table 3.2). At 42 days of age indigenous Tswana pig males had significantly higher ear length than their female counterparts with ear length of 9.86±0.14cm and 9.37±0.20cm, respectively. Similar ear lengths between male and female pig have been reported in Naga pigs of India (7.90 vs. 8.63cm in males and females, respectively), in Mali pigs (8.2 and 8.5 cm in males and females, respectively) and in Ashanti Black pig of Ghana weaners (9.5 and 9.7cm in males and females, respectively (Dandapat *et. al.*, 2010; Borkotoky *et al.*, 2014; Alenyorege and Opoku, 2015). Similar tail length between male and female indigenous Tswana pigs is consistent with Dandapat *et, al.* (2010) in Mali pigs (22.8 and 22.6 cm in males and females, respectively), Subalini *et al.* (2010) in village pigs of Sri-Lanka (28.4 and 27.94cm in males and females, respectively) and Borkotoky *et al.* (2014) in Naga pigs of India (15.36 and 17.08cm in males and females, respectively).

There were no significant differences in pelvic width between male and female indigenous Tswana pigs at all ages from day old to 98 days of age (Table 3.3). However, males had slightly higher pelvic width than their female counterparts from day old to 28 days of age while females had slightly higher pelvic width than their male counterparts from 42 days to 98 days of age. Slightly higher pelvic width in female than male Tswana pigs from 42 to 98 days of age is consistent with Borkotoky *et al.* (2014) who reported paunch girth of 71.34 and 63.94cm in female and male Naga pigs of India, respectively. Alenyorege and Opoku (2015) reported significantly higher width of the waist in female than male (25.4 vs. 16.4cm) weaners (2-3 months of age) of Ashanti black pig of Ghana. Higher pelvic width in female than male indigenous Tswana pig at 98 days of age could be an indication of the early approach of sexual maturity in females than males.

Table: 3.1: Body linear measurement of Tswana pigs raised under intensive management in South eastern Botswana

	BODY WEIGHT(KG)		BODY LENGTH(cm)		HEIGHT WITHERS (cm)	
Age in days	Male (n=58)	Female (n=70)	Male	Female	Male	Female
1	1.01^{a} ± 0.05	0.98^{a} ± 0.08	21.38^{a} ± 0.37	21.42^{a} ±0.52	15.48^{a} ± 0.31	15.37^{a} ± 0.44
14	2.95^{a} ± 0.11	2.82^{a} ± 0.16	30.28^{a} ± 0.55	31.69^{a} ±0.78	22.46^{a} ± 0.81	21.95^{a} ± 1.14
28	4.74^{a} ± 0.17	4.47^{a} ± 0.24	35.09^{a} ± 0.54	36.30^{a} ±0.76	27.66^{a} ± 0.96	26.91^{a} ± 1.35
42	7.14^{a} ± 0.20	6.84^{a} ± 0.29	40.56^{a} ± 0.60	41.92^{a} ±0.85	30.68^{a} ± 1.10	29.68^{a} ± 1.55
56	9.57^{a} ± 0.21	9.40^{a} ± 0.29	44.09^{a} ± 0.50	44.63^{a} ±0.71	33.42^{a} ± 1.14	32.81^{a} ± 1.62
70	12.08^{a} ±0.21	11.68^{a} ±0.30	46.68^{a} ± 0.44	47.21^{a} ±0.62	34.96^{a} ± 1.22	34.78^{a} ± 1.72
84	16.77^{a} ±0.36	16.96^{a} ±0.51	51.50^{a} ± 0.57	51.26^{a} ±0.81	39.08^{a} ± 1.13	38.84^{a} ±1.60
98	21.71^{a} ±0.51	22.02^{a} ±0.72	54.18^{a} ± 0.67	54.02^{a} ±0.94	43.13^{a} ± 1.10	42.83^{a} ± 1.56

Chimonyo *et, al* (2005) reported early attainment of sexual maturity in females than males in Mukota pigs of Zimbabwe with females reaching sexual maturity at 3 months of age. The higher pelvic width in female than male indigenous Tswana pig is meant to help the sow accommodate boar weight during breeding as well as to carter for pregnancy if it occurs.

Table 3.2 Body linear measurement of Tswana pigs raised under intensive management in South eastern Botswana

	Heart girth (cm)		Ear length (cm)		Hock circumference (cm)	
Age in Days	Male (n=58)	Female (n=70)	Male	Female	Male	Female
1	$22.54^{a}\pm0.37$	$22.28^{a}\pm0.52$	$5.14^{a}\pm0.11$	$5.06^{a}\pm0.15$	$5.55^{a}\pm0.09$	$5.53^{a}\pm0.13$
14	$33.61^{a}\pm0.377$	$33.05^{a}\pm0.53$	$7.06^{a}\pm0.08$	$6.96^{a}\pm0.11$	$7.03^{a}\pm0.08$	$7.08^{a}\pm0.12$
28	$38.27^{a}\pm0.40$	$38.40^{a}\pm0.57$	$8.05^{a}\pm0.09$	$7.06^{a}\pm0.13$	$8.44^{a}\pm0.09$	$8.31^{a}\pm0.12$
42	$46.65^{a}\pm0.96$	$47.10^{a}\pm1.35$	$9.86^{a}\pm0.14$	$9.37^{b}\pm0.20$	$10.15^{a}\pm0.14$	$9.88^{a}\pm0.19$
56	$49.88^{a}\pm0.93$	$50.43^{a}\pm1.31$	$11.14^{a}\pm0.16$	$10.76^{a}\pm0.23$	$11.20^{a}\pm0.16$	$11.02^{a}\pm0.21$
70	$52.64^{a}\pm1.15$	$53.54^{a}\pm1.62$	$11.92^{a}\pm0.15$	$11.67^{a}\pm0.21$	$12.04^{a}\pm0.15$	$11.83^{a}\pm0.25$
84	$56.64^{a}\pm1.19$	$57.62^{a}\pm1.68$	$13.58^{a}\pm0.19$	$13.14^{a}\pm0.26$	$13.51^{a}\pm0.18$	$13.07^{a}\pm0.25$
98	$60.25^{a}\pm1.14$	$61.40^{a}\pm1.62$	$15.07^{a}\pm0.24$	$14.39^{a}\pm0.34$	$14.97^{a}\pm0.24$	$14.28^{a}\pm0.34$

Table 3.3 Body linear measurement of Tswana pigs raised under intensive management at Sebele

	Tail length (cm)		Pelvic width (cm)	
Age in Days	Male (n=58)	Female (n=70)	Male	Female
1	6.61^{a} ± 0.26	6.69^{a} ± 0.37	9.92^{a} ± 0.25	9.83a ± 0.34
14	8.70^{a} ± 0.28	8.69^{a} ± 0.39	15.30^{a} ± 0.40	15.10^{a} ± 0.57
28	9.88^{a} ± 0.32	9.77^{a} ± 0.46	18.05^{a} ± 0.42	17.94^{a} ± 0.60
42	11.33^{a}±0.32	10.93^{a}±0.46	20.88^{a} ± 0.50	21.12^{a} ± 0.70
56	12.91^{a}±0.33	12.62^{a}±0.46	22.39^{a} ± 0.55	22.84^{a} ± 0.78
70	13.66^{a}±0.29	13.44^{a}±0.41	23.91^{a} ± 0.60	24.69^{a} ± 0.84
84	15.01^{a}±0.36	14.94^{a}±0.51	25.36^{a} ± 0.53	25.97^{a} ± 0.75
98	16.0^{a} ± 0.37	15.89^{a}±0.52	27.21^{a} ± 0.55	27.39^{a} ± 0.77

3.4.2 Reproductive Performance of Indigenous Tswana Pigs

Litter size of indigenous Tswana pigs ranged between 3 and 9 and averaged 7.63±0.40 piglets per litter at first parity and ranged between 6 and 11 and averaged 9.25±0.35 piglets per litter at second parity (Table 3.4). The litter weight at birth averaged 7.83±1.55 and 11.56±1.35kg at first and second parity, respectively. Higher litter size and litter weight at birth at second than at first parity in Tswana pigs is in agreement with Egerszegi *et al* (2003) who found positive covariation between reproductive performance and the age of the sows, the number of teats and parity. Litter size at birth of indigenous Tswana pigs at first parity is comparable to that of South African indigenous pigs (7.0) and Mukota pigs of Zimbabwe (7.9) (Chimonyo *et al.*, 2010, Ncube *et al.*, 2003). Litter size at birth of indigenous Tswana pigs is however higher than that of Sri Lankan village pig (6.44±1.19), Naga local pig (5.80±2.30) and Votho pig of Nagaland, India (ranged between 6.06±0.39 and 6.60±0.34) (Subalini *et. al.*, 2010; Borkotoky *et. al.*, 2014; Chusi *et. al.*, 2016). Litter weights at birth of indigenous

Tswana pigs at both first and second parity were higher than those of the local Votho pig of Nagaland, India from various districts which ranged between 1.75±2.45kg and 2.02±2.2kg (Chusi *et. al.*, 2016). Differences in litter size and litter weight at birth between indigenous pigs from various regions of the world could be attributed to genetic differences in indigenous pigs of different countries and also differences in the management systems of indigenous pigs between countries.

Litter size at weaning and litter weight at weaning were comparatively higher at second than at first parity (8.75±0.25 vs. 6.75 ±0.30 piglets/litter and 86.98±2.65 vs. 64.20±3.15kg/litter for the two traits, respectively) in indigenous Tswana pigs (Table 3.4) and this translated to average weaning weight per piglet at 56 days of age of 9.51 and 9.94 at first and second parity, respectively. Comparatively higher pre-weaning mortality of 11.53% was recorded at first parity compared to the 5.41 pre-weaning mortality at second parity. High pre-weaning mortality at first than second parity could be attributed to inexperience and poor mothering ability in first parity sows which improved at second parity. Litter size at weaning of Tswana pigs is comparable to those of Sri Lankan village pig (6.44±1.19), Mali pig (8.6±0.4) and Desi pig (8.40±0.32) (Subalini *et. al.*, 2010; Dandapat *et. al.*, 2010; Dimitrov *et. al.*, 2010) but comparatively higher than that of Naga local pig (4.20±1.90) (Chusi *et. al.*, 2014). Litter size at weaning and litter weight at weaning of Tswana pigs are also relatively higher than those reported for the Votho pig of Nagaland which ranged between 5.00 and 5.40 piglets/sow at weaning and between 24.82 and 26.02kg/litter for the two traits, respectively.

Table 3.4: Reproductive performance of indigenous Tswana pigs raised under an intensive management system in South eastern Botswana

Parameter	1st litter (n=54)	2nd litter (n=74)
Litter size at farrowing	7.63±0.40 (3-9)	9.25±0.35 (6-11)
Litter weight (kg)	7.83±1.55	11.56±1.35
Litter size at weaning (56d)	6.75±0.30	8.75±0.25
Litter weight at weaning (56d)	64.20±3.15	86.98±2.65
Mortality	11.53% (1-3)	5.41% (1-2)

3.5 CONCLUSIONS

Sex had no significant influence on various measures of growth performance from birth to 98d of age in Tswana pigs. Litter size and litter weight at birth and litter size and litter weight at weaning were comparatively higher at second than at first parity. Pre-weaning piglet mortality was however higher at first than second parity. The indigenous Tswana pig exhibited satisfactory growth and reproductive performance under an intensive management system.

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CHAPTER 4

GENETIC CHARACTERIZATION OF INDIGENOUS TSWANA PIG POPULATION USING MICROSATELLITE MARKERS

4.1 Abstract

The population of indigenous Tswana pigs has declined drastically in the last three decades. The indigenous Tswana pig is currently listed as an endangered animal genetic resource. If deliberate efforts towards conservation are not put in place, this valuable genetic resource might go extinct within the next decades. The indigenous Tswana pig has not been fully phenotypically and genetically characterized. The objective of this study was to assess the genetic diversity (genetic characterization) of the indigenous Tswana pig population using DNA microsatellite marker technology. Blood samples were collected from 30 randomly selected Tswana pigs in Kgatleng and South-East districts of Botswana for the assessment of genetic diversity using a panel of 12 FAO-recommended microsatellite markers. All the microsatellite markers screened in indigenous Tswana pigs were polymorphic and the number of observed alleles per marker varied between 3 (Sw2406) and 9 (Sw225) with mean number of alleles per marker of 6.33. The observed heterozygosity ranged from 0.16 (Sw2405) to 0.875 (Sw2465) with average observed heterozygosity across all 12 loci of 0.647. The expected heterozygosity was lower than the observed heterozygosity and ranged between 0.143 (Sw2405) and 0.776 (SO385) with mean expected heterozygosity across all loci of 0.603. The allelic diversity and levels of heterozygosity indicate high levels of genetic diversity in Tswana pig population. The within-locus inbreeding coefficient (F_{is}) ranged between -0.321(S0120) and 0.234 (SW35) with inbreeding coefficient of the entire population of -0.012 indicating that the Tswana pig population is relatively outbred. All the 12 microsatellite markers were in Hardy-Weinberg Equilibrium indicating high genetic stability of indigenous Tswana pigs.

Key words: genetic diversity, microsatellite markers, Tswana pigs,

4.2 INTRODUCTION

Indigenous pigs are kept by the rural populace under the low- output free range production system. Indigenous Tswana pigs are mostly owned by women and usually survive in harsh, low input environments and strive under heavy diseases, parasite and nutrients challenges (Chabo *et al.*, 2000). During the 1980's, indigenous Tswana pigs were found in South East, Kgatleng and Kweneng districts of Botswana while nowadays they are fairly well distributed in the south east district of the country in and around Ramotswa village (Nsoso *et al.*, 2006). The farmers who keep indigenous pigs in Botswana have a tendency to keep low numbers to match herd size with available feed resources. Notable attributes of indigenous Tswana pigs include disease resistance, high fertility, parasite and heat tolerance, low protein requirements, ability to utilize course fibrous rations and strong feet which make them suitable for free range low-intensity management systems affordable to the rural poor (Gandini and Oldenbroack, 1999; Lekule and Kyvsgaard, 2003).

The indigenous Tswana pigs are usually black or black with white stripes (Figure 4.1) and have a body of medium stature (Nsoso *et al.*, 2006). Indigenous Tswana pigs are however shunned away from commercial production systems due to their inferior growth and reproductive performance and carcass traits relative to exotic breeds. Resource-poor farmers in rural areas also view genetic improvement of indigenous Tswana pigs as synonymous to crossbreeding, grading up and possible breed replacement with exotic breeds.

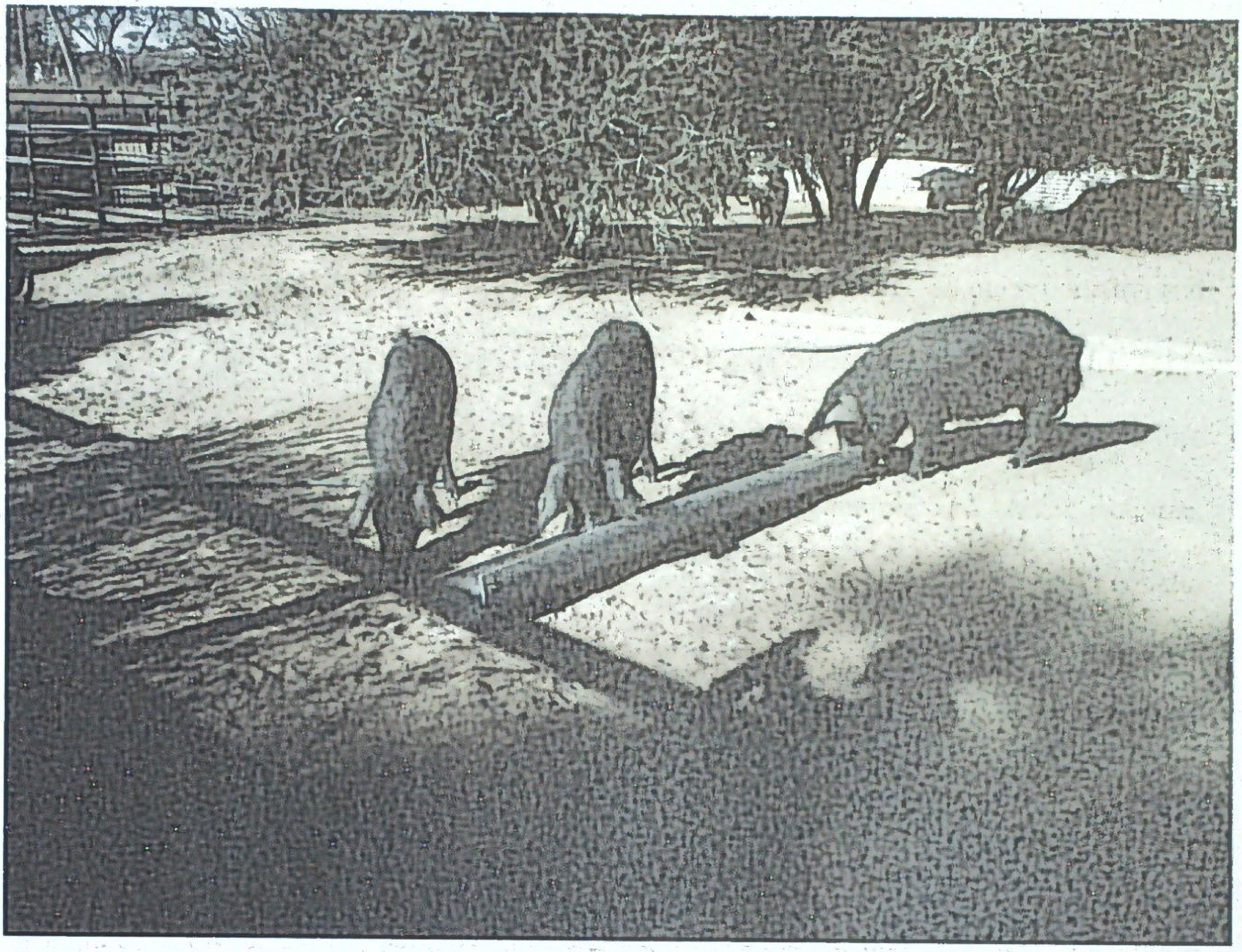

Figure 4.1: Indigenous Tswana Pigs at Department of Agricultural Research, Sebele.

Extensive system coupled with undeveloped markets for indigenous Tswana pigs and lack of a clear policy on the conservation of indigenous animal genetic resources in the country is leading to the disappearance of indigenous Tswana pigs. Such a scenario is also likely to worsen poverty for most of the rural women populace who own most of the indigenous Tswana pigs since the fast-growing exotic pigs require high levels of inputs and management unaffordable to these resource-poor and highly marginalized farmers. The population of indigenous Tswana pigs has declined drastically in the last three decades and the indigenous Tswana pig is currently listed as an endangered animal genetic resource (Podisi, 2001). If deliberate efforts towards conservation are not put in place, this valuable genetic resource with its hardiness, disease resistance and heat tolerance genes might go extinct within the next decades, even before it has been fully characterized. The conservation of indigenous Tswana pigs should be given high priority because it contains valuable genes (disease resistance and heat tolerance genes) for future breed developments and genetic engineering applications to counter the effects of global warming or climate change on pig production and productivity (Podisi, 2001). Rege and Lipner (1992) expressed serious concern that some indigenous animal genetic resources of Africa are endangered and may even be lost before they are described and documented, and the indigenous Tswana pig is a classic example. Research to evaluate the indigenous Tswana pig has been sporadic and inadequate; consequently, the indigenous Tswana pig has not been sufficiently characterized. Information on phenotypic characteristics and production performance of Tswana pigs is still very scarce and there has been no attempt to date at their genetic characterization. Genetic characterization of Tswana pigs by microsatellite markers is important to assess the degree of genetic diversity in the remaining population and the extent of inbreeding and will inform future conservation and management practices. The objective of this study was therefore to assess the genetic diversity of the indigenous Tswana pig population using microsatellite markers.

4.3 MATERIALS AND METHODS

4.3.1 Population sampling

Blood samples were collected from 30 unrelated Tswana pigs in the Southern half of the country in Kgatleng and South-East districts following the guidelines of Measurement of Domestic Animal Diversity (FAO 1995) programme. Blood samples were collected from the ear vein of the animals in vacutainer tubes containing EDTA as the anticoagulant. Blood samples were then transported to the laboratory at 0-4°C (under ice cubes) and stored overnight at -20°C prior to DNA extraction. Information on sampling locations and number of samples per sampling location is given in Table 4.1.

Table 4.1: Locations where indigenous Tswana pigs were sampled and number of samples per location

Sampling location	District	No. of samples per location
Ditshweneng lands	Kgatleng	3
Lesetlhane lands	South East	3
Metsimaswaane lands	South East	3
Mmopane	Kweneng	3
Mogobane	South East	4
Ramotswa	South East	6
Sebele (DAR)	Gaborone	2
Segakwaneng lands	Kgatleng	3
Taung	South East	3
Total		30

4.3.2 DNA Extraction

Genomic DNA was isolated from whole blood using Zymo Quick-gDNA miniPrep kit following the manufacturer's protocol. Briefly, 400µl of Genomic Lysis Buffer was added to 100µl of whole blood and completely mixed by vortexing for 4-6 seconds. The mixture was let to stand for 5-10 minutes at room temperature. The mixture was then transferred to a Zymo-Spin™ Column in Collection Tube and centrifuged at 10,000 ×g for a minute. The collection tube with the flow through was discarded and the Zymo-Spin™ Column was transferred into a new collection tube. 200µl of DNA Pre-Wash Buffer was added to the spin column and centrifuged at 10,000 ×g for a minute. 500µl of g-DNA Wash Buffer was added to the spin column and centrifuged at 10,000 ×g for a minute. The spin column was then transferred to clean micro centrifuge tube and 60µl of DNA Elution Buffer was added and incubated 2-5 minutes at room temperature. The spin column was then centrifuged at top speed for 30 seconds to elude the gDNA. The concentration of eluded gDNA was measured using a spectrophotometer (Nanodrop 2000) and the purity of the gDNA was verified by the 260/280 absorbance ratio (Thermo Fisher Scientific Inc., Waltham, MA, USA).

4.3.3 Microsatellite markers amplification and analysis

A panel of 12 microsatellites recommended by Food Agriculture Organisation (FAO)/ISAG-FAO Advisory Group on Animal Genetic Diversity (FAO, 2011) were used for genetic characterization of Tswana pigs. The markers used in the study (with chromosome position) were: SW2456 (X/Y), S0165 (3), SW225 (13), SW2008 (11), SW35 (4), SW2406 (6), S0385 (11), S0120 (18), S0073 (4), SW2443 (2), SW949 (X/Y), and SW2410 (17). Selective amplification of different microsatellites was achieved by polymerase chain reaction using the thermocycler GeneAmp PCR system 9700 (Applied Bio systems, Forster City CA, USA) and PCR reagents synthesised by Fermentas Life Sciences Opelstrasse, Germany. Each 25µl PCR reaction comprised approximately 100 ng gDNA, primers (60 ng each), dNTPs (40 mm each), 10X ammonia-based PCR buffer (2.5 µL), 1.5 mm Mg Cl2, 1 unit of Taq DNA polymerase and PCR grade deionized water. The PCR reaction was accomplished by initial denaturation for 5 minutes at 94°C, followed by 33 cycles of denaturation at 94°C for 30 seconds, primer annealing for 45 seconds at the desired temperature and DNA replication at 72°C for 1 minute. The final extension step was run at 72°C for 10 minutes. The resulting PCR products were denatured at 98°C for 3 minutes and rapidly cooled by placing on ice. The PCR products were separated by capillary electrophoresis on ABI Prism 310 Genetic Analyzer (Applied Biosystems, Foster city, CA, USA) according to the manufacturers recommendations and allele sizing was achieved by using the internal size standard of

Genescan-500 LIZ (Applied Biosystems, Foster city, CA, USA). Data on allele sizes was done using Genescan Analysis software v.3.1.2 and the identification of different alleles for each marker was performed by Genotyper 2.5 software.

4.3.4 Statistical Analysis

The within breed genetic diversity parameters for Tswana pigs which included observed heterozygosity (H_o), expected heterozygosity (H_e), polymorphism information content (PIC) and mean number of alleles (MNA) were calculated using Microsatellite Toolkit software (Kim, 2002). The inbreeding coefficient (F_{is}) for each locus was computed using the program FSTAT (Goudet, 2001). The probability test approach (Guo and Thompson, 1992) implemented in the GENEPOP software (Raymond and Rousset, 1995) was used to test each locus for Hardy-Weinberg equilibrium

4.4 RESULTS AND DISCUSSION

All the microsatellite markers screened in indigenous Tswana pigs were polymorphic (Table 4.2). A total of 76 alleles were detected in 12 microsatellite markers screened and the allele size range varied from 83-107 bp at locus S0073 to 220-234 bp at marker locus Sw2406. The number of observed alleles per marker varied between 3 (Sw2406) and 9 (Sw225) with mean number of alleles per marker of 6.33 (Table 4.2). The range of observed number of alleles per marker and mean number of alleles per marker observed in this study are comparable to 3.38-8.71 and 6.25, respectively, found in local Criollo pig breeds from the Americas (Revidatti *et al.*, 2014) but lower than the range of 5-12 alleles per marker and mean number of alleles per marker of 7.04 reported in indigenous Andaman Desi pig of India (De *et. al.*, 2013) and mean number of alleles per marker of 8.45 found in indigenous pigs of Mozambique (Swart *et. al.*, 2010). The range of observed number of alleles per marker found in this study is however, higher than the range of 3.98- 5.54 reported by Swart *et al*, (2010) in Commercial pig breeds of South Africa (Landrace, large white and Duroc).

The mean number of alleles per marker of 6.33 found in this study is comparable to 6.18 found in indigenous South African Kolbroek breed (Swart *et al.*, 2010) but higher than 5.72 found in Uruguayan Pampa Rocha pigs (Montenegro *et al.*, 2015), 3.93 and 5.97 in Namibia and Kune-kune breeds (Swart *et. al.*, 2010). Effective number of alleles in Tswana pigs ranged between 1.11 (Sw2406) and 5.01 (S0165) with mean effective number of alleles per marker of 3.31±1.18. Revidatti *et al*, (2014) reported a lower mean effective number of alleles per marker of 3.33±1.56 in Criolli pig breeds of the Americas which is comparable with the present study. The mean effective number of alleles per marker in Tswana pigs is however lower than the mean effective number of alleles per marker of 5.09±0.20 found in Andaman Desi pigs of India. According to Pandey *et al*, (2006), FAO specified a minimum of four alleles per marker for effective screening of genetic differences between breeds and all the markers used in this study with the exception of Sw2406 exhibited sufficient polymorphism for evaluation of genetic variation within breed and genetic differences between breeds.

Table 4.2 Observed and effective number of alleles found in Tswana Pigs

Marker	Allele	Na	Ne
SW2456	205, 207, 191, 209, 211, 189,	6	3.56
S0165	140, 142, 156,159, 137,136, 134,135,	8	5.01
SW225	106, 108, 94, 96, 118, 112, 116, 110, 114,	9	4.35
SW2008	94, 98,96,90,88, 92,	6	3.13
Sw35	133, 127, 132, 135, 100,	5	3.58
SW2406	220, 234, 222,	3	1.11
S0385	173, 179, 273, 171, 177, 175, 151,	7	4.53
S0120	169, 171, 151, 153, 163, 165,	6	2.18
S0073	91, 107, 113, 85, 83, 105, 90, 101,	8	3.99
SW2443	209, 211, 213, 203, 207, 201,	6	3.93
SW949	182, 184, 202, 204, 172, 188,	6	2.50
SW2410	107, 121, 118, 105, 117, 123,	6	1.88
	Means	6.33±1.56	3.31±1.18

Na=observed number of alleles; Ne=effective number of alleles

Apart from the number of alleles per locus and mean number of alleles for all loci, other measures of genetic diversity include observed heterozygosity, expected heterozygosity and polymorphic information content (PIC) and such measures in the Tswana pig are depicted in Table 4.3.

The observed heterozygosity for individual markers ranged from 0.16 (Sw2405) to 0.875 (Sw2465) with average observed heterozygosity across all 12 loci of 0.647. The expected heterozygosity was lower than the observed heterozygosity and ranged from 0.143 (Sw2405) to 0.776 (S0385) with mean expected heterozygosity across all loci of 0.603. For markers to be useful in measuring genetic variation they should have average heterozygosity between 0.3 and 0.8 (Takezaki *et al.*, 1996) and therefore all the markers used in this study with the exception of Sw2405 were appropriate for measuring genetic variation in Tswana pigs. According to Nei and Kumar (2000) observed heterozygosity and expected heterozygosity are highly correlated but expected heterozygosity also known as Hardy-Weinberg heterozygosity is considered a better estimator of the genetic variability present in a population.

More heterozygous loci than expected in Tswana pigs is consistent with Sutarno *et al.* (2015) who observed a similar pattern in most Indonesian Native cattle breeds. Unlike in Tswana pigs, most pig genetic characterization studies report heterozygote deficiencies than heterozygote excesses (De *et al*,2013) due to inbreeding resulting from limited population sizes and selective breeding in pig improvement programs. The average expected heterozygosity of 0.603 and observed heterozygosity of 0.647 indicate high level of genetic variability or genetic diversity in Tswana pigs since it is interpreted as such when the heterozygosity values exceed 0.5 (Melendez *et al.*, 2014). High degrees of genetic diversity have also been reported in indigenous pigs of Cerete-Colombia, Andaman Desi pig, Criollo pig breeds from the Americas, Uruguayan Pampa Rocha pigs and Chinese village pigs with expected heterozygosity values of 0.527, 0.77, 0.622, 0.603 and 0.826, respectively (Melendez *et al.*, 2014; De *et al.*, 2013; Revidatti *et al.*, 2014; Montenegro *et al.*, 2015 and Fang *et al.*, 2009). The expected heterozygosity value of 0.603 found in Tswana pigs is comparable to those found in other Southern African pig breeds such as Mozambique indigenous pig, South African Kolbrock and South African Kune-Kune with Hardy-Weinberg heterozygosity values of 0.692, 0.634 and 0.675, respectively (Swart *et al.*, 2010). Compared to commercial pig breeds, the average expected heterozygosity of the indigenous

Tswana (0.603) is similar to 0.60 of the large white (Cho *et al.*, 2014) but slightly higher than 0.580 and 0.531 of the South African Landrace and Duroc breeds, respectively (Swart *et al.*, 2010). The high level of genetic variation or diversity in Tswana pigs might be attributed to lack of selective breeding or improvement programs targeted to the breed and possible existence of population substructure (Genetic uniqueness in terms of alleles of Tswana pigs coming from different villages).

The polymorphic information content (PIC) values of the 12 markers employed in the characterization of Tswana pigs ranged from 0.094 for Sw2405 to 0.569 for S0385 with average PIC value of all the markers of 0.428 (Table 4.3). According to Montenegro et al. (2015), markers with PIC values greater than 0.5 are highly informative, those with PIC values between 0.25 and 0.5 are moderately informative and those with PIC values less than 0.25 are uninformative. Following the same classification criterion, four markers (Sw2008, S0385, S0073 and Sw2443) were highly informative, seven (Sw2465, S0165, Sw225, Sw35, S0120, Sw949 and Sw2410) were moderately informative and one (Sw2405) was uninformative in Tswana pigs. Moderately informative and highly informative markers are more variable and therefore more suitable for genetic diversity studies in indigenous Tswana pigs.

Table 4.3: Measures of genetic diversity in Tswana pigs

Locus	Ho	He	PIC	HWE p-value	F_{is}
Sw2465	0.875	0.679	0.47	0.648	-0.242
S0165	0.586	0.637	0.422	0.591	0.240
Sw225	0.819	0.693	0.499	0.791	-0.075
Sw2008	0.71	0.724	0.524	0.729	-0.029
Sw35	0.556	0.578	0.424	0.730	0.234
Sw2405	0.16	0.143	0.094	1.00	-0.044
S0385	0.736	0.776	0.569	0.548	-0.008
S0120	0.694	0.542	0.39	0.914	-0.321
S0073	0.622	0.704	0.517	0.698	0.218
Sw2443	0.823	0.723	0.525	0.776	-0.102
Sw949	0.743	0.551	0.378	1.00	-0.251
Sw2410	0.403	0.485	0.321	0.889	0.238
Mean	**0.647**	**0.603**	**0.428**	**0.776**	**-0.012**

All the 12 microsatellite markers used in the current study were in Hardy-Weinberg Equilibrium clearly indicating the high genetic stability of indigenous Tswana pigs kept by farmers under extensive management system. The high genetic stability of indigenous

Tswana pigs confirm that Tswana pigs are mostly random mating under free running management system practised by majority of farmers, is not undergoing any artificial selection (no improvement program for indigenous Tswana pig), the effects of random genetic drift common in small populations like that of Tswana pigs are negligible and Tswana pigs are not subjected to other evolutionary forces such as mutation and migration capable of altering gene and genotype frequencies and causing significant departures form Hardy-Weinberg equilibrium.

The within-locus inbreeding coefficient (F_{is}) ranged between -0.321(S0120) and 0.234 (SW35) with multilocus inbreeding coefficient of the entire population of -0.012. The negative inbreeding coefficient of Tswana pigs might be due to avoidance of mating among closely related animals (Hui-Fang *et al.*, 2010) which resulted in significant excess of heterozygotes in the population. All the markers with the exception of Sw35 and S0073 contributed to the negative inbreeding coefficient of the Tswana pigs. Markers Sw35 and S0073 exhibited significant deficit of heterozygotes probably due to genetic drift or linkage disequilibrium of the marker with loci under either natural or artificial selection (Ibeagha-Awemu and Erhardt, 2005).

4.5 CONCLUSIONS

Moderate levels of genetic diversity and no inbreeding exists within the Tswana pig population in Southern Botswana. This genetic diversity in the Tswana pigs shows that there is random mating and the animals are not undergoing any form of artificial selection.

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CHAPTER 5:

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL DISCUSSION

The purpose of this study was to evaluate the growth and reproductive performance of indigenous Tswana pigs under intensive management system and to evaluate the genetic diversity of the Tswana pig population using a panel of 12 porcine microsatellite markers.

A total of 12 sows of approximately six months of age were loaned from farmers in Kgatleng and South East districts of Botswana and raised intensively for evaluation of reproductive performance at first and second parity. From 12 sows only 10 sows furrowed twice and average litter size was greater at second parity at 9.25 than at first parity at 7.63. Higher litter size at second parity translated to higher litter weight at second than at first parity. Higher litter size and litter weight at second than at first parity is consistent with Ncube *et al.* (2003) who reported increasing litter size and litter weight with increasing parity in pigs. Higher pre-weaning mortality was observed at first than at second parity resulting in smaller litter size and litter weight at weaning at first than at second parity. Higher pre-weaning mortality at first than at second parity could be attributed to inexperience and therefore poor mothering ability of the sows at first than at second parity. The overall mean pre-weaning mortality for both parities was less than the acceptable value of 10% and much lower than 35% mortality recorded by Chabo *et al.* (2000) on the Large White breed kept at Botswana College of Agriculture Farm.

Growth performance was evaluated on a total of 128 piglets and growth parameters evaluated included body weight, height at withers, heart girth circumference, hock and pelvic circumference, tail length and ear length from day old to 3 months of age. There were no significant sex differences ($P>0.05$) in all growth parameters from day old to 3 months of age. The overall mean birth weight of male and female Tswana piglets at birth was 0.99±0.08 kg which is consistent with that of the Mexican native pig (0.97kg) and Nigerian indigenous pig (1.02kg) (Lemus *et al.*, 2003; Ate and Oyedipe, 2011). Female Tswana pigs were slightly longer than their male counterparts from birth to post weaning and this is consistent with Egerszgi (2003) who observed a similar pattern in both Blond Mangalica and Swallow Belly Mangalica breeds. Male Tswana pigs had slightly higher height at withers than their age-matched female counterparts from birth to post weaning (98 days) and this is contrary to Subalini (2010) who reported higher height at withers in females than males in Sri Lankan village pigs. The pelvic width was slightly larger in male Tswana pigs than their female counterparts from birth up to 42 days of age and thereafter females had larger pelvic widths than their male counterparts up to 98 days of age. Slightly larger pelvic width in females than males post-weaning could be attributed to the fact that females reach sexual maturity before males and thus sex hormones were building up in females resulting in larger pelvic width in preparation of the birth process. Chimonyo *et al.* (2005) reported that female Mukota pigs of Zimbabwe reach sexual maturity earlier than their male counterparts and with first signs of oestrus observed at 3 months of age. There were no significant sex differences in ear length, hock circumference and tail length in Tswana pigs from birth to post-weaning (98 days of age) and this is consistent with Sudhakar and Gaur (2006) who observed similar results in Indian indigenous pigs.

In the second study a total of 12 porcine microsatellite markers were used for the assessment of genetic diversity in the Tswana pig population. Blood samples were collected from a total of 30 pigs sampled from various villages in Kgatleng, Kweneng and South east districts for the genetic diversity study. All the markers were polymorphic and yielded a total of 76 alleles. The number of observed alleles per marker ranged between 3(SW2406) and

9(SW225) with the mean number of alleles per marker of 6.33. The range of observed number of alleles per marker and mean number of alleles per marker observed in this study are comparable to 3.38-8.71 and 6.25, respectively, found in local Criollo pig breeds from the Americas (Revidatti *et al.*, 2014). It is however, lower than the range of 5-12 alleles and mean number of alleles per marker of 7.04 reported in Andaman Desi pig of India (De *et al.*, 2013) and mean number of alleles per marker of 8.45 found in indigenous pigs of Mozambique (Swart *et al.*, 2010). The observed heterozygosity for individual markers ranged between 0.16 (SW2406) and 0.875 (SW2465) with mean heterozygosity across all 12 loci of 0.647. The expected heterozygosity was lower than the observed heterozygosity with a range of 0.143 (SW2405) to 0.776 (S0385) with a mean of 0.603. The mean expected heterozygosity of 0.603 and mean observed heterozygosity of 0.647 indicated a high degree of genetic variability in Tswana pigs. All the 12 loci studied were also in Hardy-Weinberg equilibrium indicating high genetic stability in the Tswana pig population. The inbreeding coefficient of the Tswana pig was -0.012 indicating an excess of heterozygotes in the population and therefore, negligible levels of inbreeding in the Tswana pig population.

5.2 CONCLUSIONS

There were no significant sex differences in growth performance of Tswana pigs from day old up to 98 days of age. Higher litter size and litter weight and lower pre-weaning mortality were recorded at second than at first parity. Moderate levels of genetic diversity exist within the Tswana pig population as indicated by high allelic diversity and high average expected heterozygosity. Tswana pigs possess sufficient genetic variation for future genetic improvement programmes to counter the effects of global warming and climate change.

5.3 RECOMMENDATIONS

(i) Further studies on growth performance (measurement of various growth parameters) of Tswana pigs from 3 months of age until sexual maturity should be carried out.

(ii) The government and Institutions like Universities should lead efforts towards conservation of indigenous Tswana pigs.

(iii) Farmers should be encouraged to keep the indigenous Tswana pig for future breed developments in the face of global warming and climate change.

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