GROWTH PERFORMANCE OF MUSCOVY AND PEKIN DUCKS UNDER AN INTENSIVE MANAGEMENT SYTEM AND ASSESSMENT OF GENETIC DIVEISIYT OF MUSCOVY DUCK POPULATION IN BOTSWANA

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

BY

BAAGI MOTHANKA

SEPTEMBER 2020

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

BAAGI MOTHANKA

Faculty of Animal and Veterinary Sciences

Department of Animal Sciences

Botswana University of Agriculture and Natural Resources

Main supervisor: **Prof. Patrick M. Kgwatalala**

Co-supervisors: **Prof. Shalaulani J. Nsoso**

Prof. Essau E. Waugh

September 2020

DECLARATION

I declare that the thesis hereby submitted by me for the Master of Science degree (Animal Science) at Botswana University of Agriculture and Natural Resources, is my own independent work and has not been 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 has been duly accredited.

B. Mothanka

Baagi Mothanka

September 2020

APPROVAL

Main supervisor's name	Date	Signature
P.M. KGWATALALA	18/09/2020	[signature]
Co-supervisor's names	**Date**	**Signature**
E E KIAUGH	21-09-2020	[signature]
S.J. NDOSU	28-09-2020	[signature]
Head of Department's name	**Date**	**Signature**
P.M. KGWATALALA	28/09/2020	[signature]

ABSTRACT

A research study was carried out to compare growth performance of Muscovy (Cairina moschata domestica) and Pekin ducks (Anas platyrhynchos) and to evaluate the genetic diversity of Muscovy duck population in Botswana. A total of 64 Muscovy and 64 Pekin ducks were individually identified using leg bands and raised under deep litter management system. The ducklings were fed commercial broiler starter crumbs (day old to 2 weeks of age) and commercial broiler grower pellets (3-16 weeks of age) and their feed intake was recorded daily, and live weights were recorded on a weekly basis from 3 to 16 weeks of age. Generally, Pekin ducks (combined male and females) had significantly higher feed intake (P<0.05) than their age-matched Muscovy counterparts from 3 weeks (436.63±7.37 vs. 298.54±7.37g, respectively) to 13 weeks (473.22±1.77 vs. 467.56±1.77g, respectively) of age. Muscovy ducks had significantly better feed conversion efficiency than Pekin ducks from 6 weeks (10.38±0.03 vs. 16.46±0.03) to 16 weeks (58.96±0.92 vs. -159.59 ± 0.92, respectively) of age. Pekin ducks (combined male and females) had significantly higher body weight than Muscovy ducks from 3 weeks (740.32±19.35 vs. 451.42±19.35g, respectively) to 7 weeks (2567.44±32.84 vs. 2128.82±32.84g, respectively) of age. Muscovy females had lower body weights than Pekin females at all ages from 3 weeks (363.48 ±19.35 vs. 710.10 ±19.35g, respectively) to 16 weeks (1991.51±37.07 vs. 2714.89±37.07g, respectively) of age while Muscovy drakes had significantly superior growth performance than Pekin drakes from 12 weeks (3507.95±38.79 vs. 3311.60 ±38.79g, respectively) to 16 weeks (4051.56 ±37.66 vs. 3192.00 ±37.07g, respectively) of age. Early enhanced growth performance of Pekin ducks (both males and females) therefore makes them more suitable candidates for broiler or meat type ducks than Muscovy ducks. The objective of the second study was to evaluate the genetic diversity of the indigenous Muscovy duck population in Botswana using a panel of 8 chicken microsatellite markers. Genomic DNA was extracted from 25 randomly selected Muscovy ducks from 8 villages in the Southern half of the country for microsatellite marker analysis. Observed and effective number of alleles ranged between 5 and 12 and between 2.495 and 5.189, respectively. The mean observed and effective number of alleles in Muscovy ducks was 8.25 and 3.66, respectively. The observed heterozygosity ranged between 0.435 and 0.913 with mean observed heterozygosity of 0.733± 0.164, while the expected heterozygosity ranged between 0.613 and 0.825 with mean expected heterozygosity of 0.725±0.078. The allelic diversity and mean observed and expected heterozygosity all translated to high levels of genetic diversity in the indigenous Muscovy duck *population. Only four loci studied were in Hardy-Weinberg equilibrium and the inbreeding coefficient was -0.136 indicating that the population was outbred and therefore had negligible levels of inbreeding. Results indicate that Muscovy duck population displayed sufficient genetic variation for within breed selection in traits of economic importance and to withstand anticipated environmental changes resulting from global warming and climate change.*

Keywords: genetic diversity, growth performance, microsatellite markers, Muscovy ducks, Pekin ducks

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ACRONYMS AND ABBREVIATIONS

BUAN	Botswana University of Agriculture and Natural Resources
BW	Body weight
BWG	Body weight gain
DNA	Dioxyribonucleic acid
FAO	Food Agriculture Organisation
FCR	Feed conversion ratio
FI	Feed intake
F_{is}	Inbreeding coefficient
GLM	General Linear Models
He	Expected Heterozygosity
Ho	Observed Heterozygosity
HWE	Hardy-Weinberg Equilibrium
L	Litre
Na	Observed Number of alleles
Ne	Effective Population size
PCR	Polymerase Chain Reaction
PIC	Polymorphic Information Content
SAS	Statistical Analysis System
SD	Standard deviation
µl	Microlitre

°C	Degrees Celsius
%	Percentage

CHAPTER 1: GENERAL INTRODUCTION

1.1 INTRODUCTION

In Africa, poultry is an important component of agricultural production system and play many socio-economic roles in the lives of rural population. Ducks represent the second largest poultry population in Africa after chicken (Teguia *et al.*, 2007). Ducks are less exigent for feed quality and less susceptible to diseases than chicken (Modak, 1996 as cited by Bhuiyan *et al.*, 2005) and their production in large numbers could be a rapid solution to protein shortage in Africa. Moreki (2011) reported that Botswana imports its duck meat from South Africa. The Botswana Poultry Annual Report of 2010 also reported that Botswana import of duck meat ranged between 2 tons and 2.3 tons between 2006 and 2008 (Moreki, 2011). Potentially, a variety of duck breeds (Pekin, Muscovy, Khaki Campbell and Mule) are available for production. Feed stuffs (conventional, non-conventional and agricultural by-products) are also readily available, and duck meat and products have good market prospects especially in Asian countries (Adzitey, 2012).

Ducks are reared in all regions of the world and the size and trends of their production are highly diversified and influenced by tradition and culture of particular regions. In Botswana duck production occurs at a subsistence scale mostly in rural areas under traditional management system and commercial duck production is non-existent in the country. South-Eastern Asia contributes 83% of global duck production (Cherry and Morris, 2008) and China currently raises the largest population of ducks. Physicians recommend people to limit consumption of red meat in favor of poultry meat due to the increased risk of cardiovascular pathologies in human after consumption of beef (Pfeuffer, 2001). There is therefore continuous increase in the consumption of poultry meat in many countries. Ducks are able to adapt to a wide range of environmental and natural conditions, which may be the reason for their increasing importance, and the popularity of the duck industry in many countries in the world (Solomon *et al.*, 2006 and Galal *et al.*, 2011).

Intensive breeding and selection of ducks have resulted in the production of duck breeds and strains with desirable meat quality traits and improved growth performance (Zhou, 2011). Further improvements in growth performance and desirable meat quality traits will however depend on the existing genetic diversity and conservation of the existing diversity for future breed developments. Maintenance and preservation of the existing genetic diversity in the duck population will ensure future development of the duck industry and long-term sustainability of the industry capable of responding to unpredictable future climatic and market demands. Evaluation of genetic diversity in existing duck populations or duck breeds is therefore very useful in providing useful information to maintain and exploit genetic resources and for providing baseline data for future comparisons and assessment of various management interventions on genetic diversity. Assessment of genetic diversity in different duck breeds also offer the opportunity to establish genetic relationships between populations or breeds and is very important for our understanding of the history of species and even of evolutionary processes (Wu *et al.*, 2009). Breed characterization requires knowledge of genetic variation that can be effectively measured within and between populations (Gholizadan *et al.*, 2007)

1.2 Justification

Considerable information is available on the growth performance of Pekin and Muscovy ducks under different production systems in other parts of the world but their growth performance under Botswana weather conditions has never been evaluated. The Muscovy has traditionally been kept by small-scale farmers in different parts of Botswana and is well-adapted to the low input-low output production environment of resource-poor farmers. The influx of fast-growing and highly productive Pekin ducks from China into Botswana threaten the genetic diversity of Muscovy ducks through indiscriminate crossbreeding. Therefore, Muscovy duck genetic diversity should be assessed to provide baseline data for future monitoring of genetic diversity trends and to inform future conservation and management decisions. The purpose of the study was therefore to evaluate growth performance of Muscovy and Pekin ducks raised intensively and to assess the genetic diversity of the Muscovy duck population in Botswana.

1.3 Study objectives

This study was undertaken to compare growth performance, feed intake and feed conversion efficiency of Muscovy and Pekin ducks raised under intensive management system and to assess the genetic diversity of Muscovy ducks using chicken microsatellite markers.

1.3.1 Specific objectives

The specific objectives of this study were to:

1. To compare the weekly weights, feed intake and feed conversion ratio of Muscovy and Pekin ducks fed commercial feeds from 3 weeks to 16 weeks of age.
2. To determine the level of genetic variation and the inbreeding coefficient of Muscovy duck population using microsatellite markers.

1.4 Hypotheses

The hypotheses tested were:

H_{01}: There are no significant differences in weekly weights, feed intake and feed conversion ratio between Muscovy and Pekin ducks of similar ages raised under an intensive management system.

H_{A1}: There are significant differences in weekly weights, feed intake and feed conversion ratio between Muscovy and Pekin ducks of similar ages raised under intensive system.

H_{02}: There is no genetic diversity or genetic variation in the Muscovy duck population of Botswana.

H_{A2}: There is considerable genetic variation or genetic diversity in the Muscovy duck population of Botswana.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

The true Pekin duck originated in China and is now widespread throughout the world (Yakubu *et al.*, 2015). Pekin ducks have an upright carriage, cream feathers and bright orange legs, feet and bill. Their eyes are dark blue and the head is characterized by bulky cheeks (Kent, 2011). The Pekin duck is a dual-purpose breed (kept for both meat and eggs) with adults weighing 3.63 to 4.99 kg and females laying 140-200 eggs per year. The breed is generally too heavy to fly, and is considered the easiest of all breeds to dress. The average lifespan of Pekin ducks is 9 to 12 years (MacDonald, 2012). Pekin ducks reach market weight early and are fairly good egg producers, but they are poor setters and seldom raise a brood (Hamre, 2009).

Muscovy Ducks are native to Latin America and are one of the greater wood ducks belonging to the genus *Cairina* included in the tribe Cairinini belonging to subfamily Anatine of family Anatidae (Goel and Goel, 2016). The plumage of Muscovy ducks can be black, white, and combination of the two or multi-colored (Raji *et al.*, 2009). Muscovy ducks are unrelated to other domestic ducks and are good foragers and good egg setters. Muscovy males are much larger than their female counterparts at market age (Hamre, 2009). The Muscovy is a dual-purpose breed, desirable for both meat production and egg-laying. Muscovy meat is unique in that it is stronger tasting, tender, less greasy, leaner, and sometimes compared to veal or roast beef. White breeds are the most desirable for meat production due to skin color and ease of dressing (MacDonald, 2012).

2.2. Comparative Growth Performance of Pekin and Muscovy ducks.

Bhuyain *et al.* (2005) reported significantly heavier weight for Pekin than Muscovy from two weeks (330 vs. 221g) to nine weeks (1763 vs. 1225g) of age. Rashid *et al.* (2009) observed that there were no significant differences in body weights between Pekin and Muscovy ducks from two weeks (180 vs. 185g) to six weeks of age (685 vs. 700g) but Muscovy ducks were significantly heavier than Pekin ducks from six weeks to ten weeks of age. According to St, eczny *et al.* (2015) the body weights of Pekin ducks were significantly higher those of Muscovy from one week (241 vs. 140g) to six weeks of age (2885 vs. 2525g), but at seven weeks of age their weights did not differ (3102 and 2971g for Pekin and Muscovy ducks, respectively). Pekin males and females were significantly heavier than Muscovy males and females only at four weeks of age (1045 vs. 1013g and 915 vs. 769g), respectively, whereas at sixteen weeks of age male Muscovy ducks were significantly heavier (4918 vs. 3005g) than male Pekin ducks (Tai and Rouvier, 1998). Omojola (2007) also reported significantly higher body weight in Muscovy females than Pekin females at ten weeks.

2.3. Sexual Dimorphism in Body Weight in Ducks

Sari *et al.* (2013) found no significant differences in body weight at two weeks (362.83 vs. 341.42g) and four weeks of age (1085.00 vs.1019.00g) between male and female Pekin ducks respectively. Farhat *et al.* (2000) and Sari *et al.* (2013) reported Pekin ducks males to be significantly heavier than their female counterparts from five weeks (2594 vs. 2471g) to seven weeks of age (3458 vs. 3266g) and from six weeks (1823 vs. 1677g) to eight weeks of age (2489 vs. 2313g) in the two studies, respectively. Witak (2008) and Isguzar *et al.* (2002) also reported significantly higher body weight in male Pekins than their female counterparts from seven weeks (3190 vs. 3031g) to nine weeks of age (3480 vs. 3282g) and from four weeks (192.8 vs.1157.7g) to twelve weeks (2007 vs. 1791.8g) of age, respectively. Wawro *et al.* (2004) reported significantly higher body weights in male than female Muscovy ducks at twelve weeks of age (4451±355.6g vs. 2397±112.4g) and in Pekin males than females at seven weeks of age (3008±231.0g vs. 2726±200.6g). Omojola (2007) also found that male Pekin and Muscovy ducks had higher body weight than their female counterparts at ten weeks of age (2000 vs. 1466.70g and 2000 vs. 1585.30g, respectively), and similar results were reported by Galal *et al.* (2011). Kleczec *et al.* (2007) and Teguia *et al.* (2008) reported significantly higher body weight in male Muscovy ducks than their female counterparts from four weeks of age to ten weeks of age and from three to twelve weeks of age, respectively. Pingel (1999) reported that different duck breeds differ in growth rates and in the degree to which males grow faster than females. The Pekin ducks typically exhibit early growth with a difference of 10 % in size between sexes, while the early growth of Muscovy ducks is usually quite slow and they develop a marked difference in weight between sexes with maturity. Baeza *et al.* (2001) reported similar day old body weights of male and female ducks (about 45 g) and significantly higher body weight in males than females from 4 weeks to 15 weeks of age (4573± 408 g vs. 2879 ± 210 g at 15 weeks of age, respectively). Teguia *et al.* (2008) also indicated that African Muscovy males were significantly heavier than their female counterparts from two weeks (113 vs. 89.6g) to twelve weeks (1832 vs. 1249g) of age. The sexual dimorphism in body weight in favor of males observed in ducks has also been reported in chickens (Nthimo, 2004; Raach-Moujahed *et al.*, 2011).

2.4. Production systems for Ducks.

Ducks can be reared under three production systems which are free-range, semi-intensive and fully intensive confinement rearing systems.

2.4.1 Free range system.

Indigenous Muscovy ducks in Botswana and most African countries are kept under backyard or free-range management system. Under this system, ducks are not confined and are thus allowed to freely roam around the backyard or around the homesteads to scavenge for any available food in the surroundings (Azahan and Mokhtar, 1984). Under the free-range management system ducks are occasionally fed with leftover food from the kitchen or surplus grains. In Nigeria, 90% of indigenous Muscovy ducks are reared under extensive system with little or no feed supplementation (Ola, 2000). Dong and Ogle (2006) reported poor growth performance of Muscovy ducks under free-range management system as compared to other research reports where improved managements systems were used and attributed this to poor nutrition under the free-range management system.

2.4.2 Semi-Intensive Production System

Under the semi-intensive management system, ducks are confined in an enclosure which has a shed for shelter, and a run and a pool of water or a free-flowing stream for swimming. Being water fowls, a pool is provided for the ducks for swimming and for proper growth and development (Azahan and Mothtar, 1984). In Botswana, the semi-intensive production system of ducks is mostly practiced in urban and peri-urban areas whereas the free-range production system predominates in rural areas. Under the semi-intensive production system, ducks are only kept enclosed at night and during the day freely roam outside in search of feed. The shelter mostly provide night shelter and nests for laying eggs. The main advantage of the semi-intensive over the intensive duck production system is that some potential factors affecting duck welfare cited by Jones *et al.* (2005) such as ventilation, temperature, humidity, litter condition and atmospheric ammonia do not affect duck performance.

2.4.3 Intensive (Confinement) System.

The ducks are kept enclosed permanently in a covered shelter (indoor system) with or without a pool inside the shelter. A fully intensive confinement rearing system for ducks, similar to that used for broiler chickens, is not commonly practiced in Botswana although it is common in the USA and many European countries. The permanently indoor production system is for large-scale duck farms, where production is mechanized to reduce labor costs. The system requires more investment than the other two production systems in terms of housing. Farmers also have to provide all feed and water and clean the house regularly. If properly managed, the fully confinement intensive duck production system can result in fast growth of ducks. Jones and Dawkins (2010) studied ducks reared under fully confinement intensive systems and highlighted the importance of maintaining a good micro-climate (humidity and ammonia concentrations), lighting and dry litter for good health and production performance.

2.4.3.1 Ammonia Concentration.

Ventilation rates and house conditions must provide sufficient fresh air for the ducks at all times. Air quality, including dust levels and concentrations of carbon dioxide, carbon monoxide, hydrogen sulfide and ammonia, must be controlled and kept within limits to ensure duck welfare is not negatively affected (Maple Leaf Farm, 2018). Ammonia levels must be monitored during each field technician visit and recorded on the field technician report and flock record (Maple Leaf

Farm 2018). Wet litter and high ammonia were also implicated in worse gait, and increasing ammonia was implicated in the incidence of foot pad dermatitis (Jones and Dawkins 2010).

2.4.3.2 Quality Litter

Litter is used primarily for the purpose of keeping the birds clean and comfortable. It absorbs moisture from the droppings and then gives this moisture to the air brought in by ventilation. A good litter is highly absorbent and fairly coarse, so as to prevent packing. It should be free from mold and contain a minimum amount of dust (Ensiminger, 1992). According to Musa *et al.* (2012), careful selection, adequate management and proper storage and utilization of poultry litter are of paramount importance to reduce environmental pollution, disease spread and economic losses associated with poultry litter. According to Mohammed *et al.* (2019) growth parameters of ducks were better in plastic slatted and sawdust litter floor, respectively, while the lowest growth parameters were in non-bedding floor. At five weeks of age the average live weight of ducks were 3175.4g, 3260.6g, 3044.3g and 2785.5g in duck houses bedded with wood shavings, plastic slatted, sand and no bedding, respectively.

2.4.3.3 Lighting

Although duck production in most developing countries is carried out under natural lighting under the free-range production system, under the fully confinement intensive production system it is desirable and in fact necessary to have houses wired so that lights can be turned on when desired. In addition, lights are usually provided in the yards for fattening ducks and are used at night and during storms to keep the ducks from stampeding (Lamon 2011). Erdem *et al.* (2015) reported lower body weight gain ($P < 0.001$) in an experiment with increased darkness due to reduced activity and feed intake. The ducks in prolonged darkness consumed less feed (5202.42g vs.

6658.32g/bird) and had lower body weight (2482.37g vs. 3069.16g/bird) compared to ducks reared under prolonged light.

2.5. Influence of Rearing Systems on Growth Performance of Ducks

Etuk *et al.*, (2006) compared the growth performance of Nigerian Muscovy ducks under semi-intensive, intensive management system with wallow and intensive management system without wallow and found no significant differences in average daily gains (16.07g, 16.39 and 15.87g/d for the three systems respectively), feed intakes (128.54, 130.68 and 131.14 g/d) and feed conversion ratios (11.56, 11.44 and 12.16) between the three systems, respectively. Similarly, Azahan and Mokhtar (1984) found no significant differences in body weight (2.59 vs. 2.83kg), feed intake (10.76 vs. 11.05 kg/d), feed efficiency (4.22 vs. 3.96) and mortality (5.2 vs. 4.3 %) between Pekin ducks raised under semi-intensive and intensive rearing systems, respectively, at 8 weeks of age.

2.6 Health management

Modern duck production is aimed at maximizing the number of ducklings produced per breeder female at point of lay that are able to reach slaughter age or kilograms of duck meat per breeder female at point of lay (International hatchery Practice- Volume 19 number 6). One of the key factors to achieving this target will be the health status of the breeder flock and their progeny until maturity. The key to achieving this is through strict adherence to biosecurity measures to keep diseases out of the duck farm and vaccination against duck diseases known to be endemic in the area. Recommended vaccination schedule for breeder ducks is depicted in Table 2.1. Ducks have the advantage over chickens in that they are hardy and have better adaptation to harsh environmental conditions (Adzitey and Adzitey, 2011) and are more resistant to most poultry diseases than chickens. Some common diseases of ducks in Botswana include Vibrio fluvialis, fowl pox, helminthiasis and colisepticaemia (Moreki *et al.*, 2011). Other common viral diseases which affect ducks are Duck virus hepatitis, duck plague, reiovirus infection of Muscovy ducks and parvovirus infection of waterfowls (Maple Leaf farm , 2018).

Table 2.1 Vaccination Program for Duck Breeders

Age in weeks	Vaccine	Route	Type
4	Duck viral hepatitis	SC	Live vaccine (Type 1)
4	Duck viral enteritis	SC	Live vaccine
10 and 20	*R anatipestifer*	SC	Bacteria
10 and 20	Duck viral hepatitis	SC	Killed virus vaccine (Type 1)

(Source: Steward-Brown, 2019)

2.7 Nutrition

Feed is one of the most important factors to consider in any farming venture and constitute about 70% of total production cost (Singh *et al.*, 2009). Regardless of how ducks obtain their food, whether it be by scavenging, or consuming a complete ration, the food consumed must contain all the nutrients, in an available form, that are needed for maintenance, growth and reproduction (Dean, 2008). Compared to chickens, very little research has been done on the nutritional requirements of ducks. Protein and energy are the first nutritional requirements that should be considered in diet formulations because they are the most expensive, but also because of their impact on the productive and reproductive performance of poultry for meat or egg production

(Fouad *et al.*, 2018). Fan *et al.* (2008) found significantly increased live weight gain and significantly reduced feed intake and feed:gain in Pekin ducks as dietary energy increased from 2,600 to 3,100 kcal of AME/kg. In the same study, increasing dietary energy levels resulted in improved feed conversion efficiency as a result of reduced feed intake and negative effects on carcass quality by increasing body fat deposition. The researchers recommended approximately 3,000 kcal of AME/kg for optimal weight gain and feed:gain when dietary protein was 18%. Wickramasuriya (2016) reported an almost similar figure of 2,900 kcal of AME/kg with 18% crude protein in order to maximize weight gain in native Korean ducks. Thongwittaya *et al.* (1992) however recommended 2,700 kcal of AME/kg with 16.5 crude protein in order to maximize productive performance of laying ducks from 18 to 37 weeks of age. Some early research indicates that ducklings have a higher protein requirement for the first two weeks of life (20% of the diet should be protein) but the protein requirement decreases rapidly after this age (Ferket, 2007). Xie (2017) found that decreasing dietary CP had no significant negative effects on weight gain and feed intake of ducks ($P > 0.05$) but the feed/gain of growing Pekin ducks increased ($P < 0.05$) when dietary CP decreased from 17.22 to 13.54%. Apart from the energy and crude protein, other nutritional requirements of ducks are shown in Table 2.2 below.

Table 2.2 Nutrient requirements for Ducks.

Nutrient	Starter (0-8 weeks)	Grower (9-20 weeks)	Layer	Breeder
ME Kcal/kg	2750	2750	2650	2650
Lysine	% 0.70	0.65	0.75	0.60
CP%	22	16	18	15
Methionine %	0.40	0.30	0.29	0.27
Ca %	0.65	0.60	2.5	2.75
Phosphorus %	0.40	0.30	0.45	0.30
Vitamin A , IU	2500	2500	6000	4000
Vitamin D3, ICU	400	400	1000	900
Vitamin E Mg	10	10	20.00	10
Vitamin K Mg	0.50	0.50	2.00	0.50
Riboflavin ppm	4	4	5.00	4
Pantothenic acid ppm	11	11	15.00	11
Niacin ppm	55	55	55.00	55
Pyridoxine ppm	2.5	2.5	6.00	3.0

(Adapted from Ghosh, 2014)

2.8 Suitable Temperature

Exposure of poultry to chronic environmental temperatures (high or low) during the course of production has adverse effects on body weight, body weight gain, feed conversion efficiency, meat yield, immune response and mortality (Washburn, 1985; Howlier and Rose, 1989). Exposure of poultry to high ambient temperature has more detrimental effects on body weight, body weight gain, feed intake and feed conversion efficiency than exposure to low and moderate ambient temperatures (Olanrewaju *et al.*, 2010). Exposure of broilers to high ambient temperature resulted in significantly reduced body weight (3.075 vs. 3.661 and 3.910 kg), feed intake (6.497 vs. 7.302 and 7.673 kg) and feed conversion ratio (2.598 vs. 2.011 and 1.977 Kg) and carcass weight (2.31 vs. 2.67 and 2.79 kg) as compared to exposure to moderate and low ambient temperature, respectively (Olanrewaju *et al.*, 2010). At the time of hatching, ducklings require a high temperature of about 30°C as at day old, ducklings are not yet able to regulate their body temperature and must have supplemental heat such as that provided by a brooder. As they grow older they become better able to produce and conserve heat, and regulate their body temperature. After the ducklings have been fully covered with feathers they are able to maintain proper body temperature even when the outside temperature is low (Dean *et al.*, 2008). Recommended ambient temperatures for ducks at various ages or developmental stages are shown in Table 2.3 below.

Table 2.3 Optimum Temperatures for Ducks

Age of ducks (days)	°C
1	30
7	27
14	23
21	19
28	15
35	13
42	13
49	13
Developing breeders	13

(Source: Dean *et al* 2008)

2.9 Feed intake and Feed conversion ratio of Muscovy and Pekin ducks.

Bhuyain *et al.* (2005) reported significantly higher feed consumption for Pekin than Muscovy from one week (313.12 vs. 244.80g) to nine weeks (4409 vs. 3608g) of age and they also reported significantly better feed conversion ratio (FCR) for Pekin than Muscovy ducks from one week (2.95 vs. 3.98) to nine weeks (2.36 vs. 2.58) of age. Galal *et al.* (2011) reported significantly higher feed consumption in Muscovy ducks than Pekin ducks at twelve weeks (3007 vs. 2321) of age and significantly better overall feed conversion ratio for Muscovy than Pekin ducks (2.37 vs. 2.48) at the same age. Rashid *et al.* (2009) observed no significant difference in feed consumption between Pekin and Muscovy ducks but Pekin ducks had comparatively higher feed consumption from one week to ten weeks of age. In the same study, feed efficiency was higher at all ages in Pekin ducklings and significantly higher ($P<0.01$) at four weeks (2.6 vs. 3.0) and five weeks (2.8 vs. 3.3) of age.

2.10 Molecular Characterization of Ducks

Microsatellite markers are useful in determining not only the level of heterozygosity but also in estimating genetic distances between breeds or between subpopulations within breed or closely related species (Chen *et al.*, 2004). Microsatellite markers are also suitable for measurement of genetic parameters such as observed and effective number of alleles as well as the polymorphism information content (PIC) in a population and can also detect rare alleles in a population (Bartfai *et al.*, 2003). Some measures of genetic diversity in a population include observed and effective number of alleles, observed and expected heterozygosity, polymorphic information content, inbreeding coefficient and Hard-Weinberg Equilibrium.

2.10.1 Observed and Effective number of alleles

Khan Ahmadi *et al.* (2007) studied the genetic structure of Pekin and Muscovy duck populations in Northern Iran using a panel of 10 microsatellite markers and reported a total of 44 alleles across all loci 100 typed individual ducks. The mean number of alleles per locus across the two breeds was 4, which indicated reasonable allelic diversity in the two duck breeds. The mean observed and effective numbers of alleles were 2.22 and 2.029 in Pekin and 2.44 and 2.18 in Muscovy ducks, respectively. Li *et al.* (2006) reported a range of 5 to 13 observed alleles per marker and mean observed number of alleles per marker of 8.428 and mean effective number of alleles per marker of 4.8 in Chinese native ducks. Gaur *et al.* (2016) reported the mean observed and effective number of alleles per marker of 11.29 and 4.29 in Coastal ducks, respectively. Su and Cheng (2009) reported a range of 5 to 15 observed alleles per marker and mean number of alleles per marker of 12.2 in Chinese indigenous laying type ducks. Goel and Goel (2016) reported a range of 4 to 26 observed alleles per marker and mean observed number of alleles per marker of 11.46 and mean effective number of alleles of 5.02 in Indian Muscovy ducks. Similarly high mean observed number of alleles (10.09) and mean effective number of alleles (4.67) per marker were reported by Mukesh *et al.* (2011) in Indian ducks. Several other researchers (Wu *et al.*, 2009; Seo *et al.*, 2016; Isomogowoti and Purwatini, 2010; Su and Cheng, 2009; Li *et al.*, 2006; Liu *et al.*, 2008) used microsatellite markers to genetically characterize their native ducks and found mean observed and effective number of alleles of more than 4 alleles per marker. All these translated to high levels of allelic diversity in most duck populations of the world and considerable genetic diversity in various duck breeds that could be exploited to increase their overall productivity.

2.10.2 Observed and Expected Heterozygosity

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. Generally, for markers to be considered useful for measuring genetic variation in a population they should have average heterozygosity between of 0.3 and 0.8. In most duck studies, the mean observed heterozygosity was less than the mean expected heterozygosity such as 0.496 and 0.606 in Chinese indigenous ducks (Liu *et al.*, 2008), 0.63 and 0.72 in Indian ducks (Mukesh *et al.*, 2011), 0.514 and 0.606 in Beijing ducks (Wu et al., 2009), 0.693 and 0.698 in Chinese Indigenous laying duck (Su and Cheng, 2009), 0.492 and 0.623 in Asian ducks (Seo *et al.*, 2016), 0.40 and 0.68 in Coastal ducks (Gaur *et al.*, 2016) and 0.54 and 0.73 in Indian Muscovy ducks, respectively. Some studies however, reported higher mean observed heterozygosity than mean expected heterozygosity. Khan Ahmadi *et al.* (2007) reported mean observed heterozygosity of 0.53 which was higher than mean expected heterozygosity of 0.43 in Pekin ducks. The mean heterozygosities (both expected and observed) reported in all the above studies were above 0.3 indicating that the markers used in the various studies were useful or were better estimators of genetic variability in the respective populations. High expected heterozygosity values reported in most studies above could be attributed to low levels of inbreeding and lack of artificial selection programs in ducks.

2.10.3 Polymorphic Information Content (PIC)

Polymorphic Information Content (PIC) is a parameter for indicating genetic variation and for measuring the marker's informativeness in population studies (Felmer *et al.*, 2008). The values range from 0 (no genetic variation and less usefulness of the marker in population studies) to 1 (high genetic variation and high usefulness of the marker in population studies. A PIC value of greater than 0.5 is considered to be highly informative, whereas a value 0.5>PIC>0.25 is considered to be reasonably informative and PIC<0.25 is less informative (Botstein *et al.*, 1980). Mukesh *et al.* (2011) reported average PIC of 0.68 from 18 loci in Indian duck populations, Ismogowati and Purwatini (2010) reported average PIC of 0.710 from 6 loci in local Indonesian ducks, Seo *et al.* (2016) found average PIC of 0.584 from 24 loci in Asian ducks, Li *et al.* (2006) found average PIC of 0.72 in Chinese native ducks, Hui- Fang *et al.* (2010) found average PIC of 0.579 from 29 loci in Chinese Indigenous egg type ducks and lastly Wu *et al.* (2008 and 2009) reported average PIC of 0.762 from 20 loci and 0.573 from 18 loci, respectively. All the above studies reported average PIC value above 0.5 indicating that the markers used in the various studies were very informative.

2.10.4 Inbreeding Coefficient (F_{is})

According to Groom *et al* (2006) Inbreeding Coefficient (F_{is}) or F-statistics 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. When there are fewer heterozygous individuals than expected, F_{is} will be positive and when there are more heterozygous individuals than expected, then F_{is} will be negative. Therefore, negative values for F_{is} indicate excess of heterozygotes in a subpopulation and positive values indicate a deficiency of heterozygotes or excess of homozygotes in a subpopulation. Most duck studies found positive F_{is} such as 0.03 in Indian ducks, 0.28 in costal ducks, 0.158 in Beijing and Cherry valley ducks and 0.647 in six duck populations (Mukesh *et al.*, 2011; Guar *et al.*, 2016; Wu *et al.*, 2009; Wu *et al.*, 2008). Goel and Goel (2016) reported overall F_{is} value of 0.248 which was significantly different from zero and points to a relative increase of 20% in homozygous loci in individuals within the population of Indian Muscovy ducks (F_{is} values were positive for 20 out of 24 loci studied). Hui-Fang *et al.* (2010) reported F_{is} value of -0.506 in Chinese Indigenous egg type ducks and the reason for negative F_{is} might be avoidance of mating closely related animals or outbreeding in Chinese egg type ducks.

2.10.5 Hardy-Weinberg Equilibrium (HWE)

When a population is in Hardy-Weinberg equilibrium for a given genetic locus it means that there is random mating (with respect to that locus), no selection, no mutation, no gene flow and the population is large enough to avoid the random effects of genetic drift (Baker's curriculum unit). According to Cartwright (2004), a goodness-of-fit test can be used to determine if a population is in Hardy-Weinberg equilibrium. According to Gaur *et al.* (2016) in West Bengal duck populations 21 out of 24 loci deviated from Hardy-Weinberg equilibrium using chi square test while 3 loci showed no significant departure from Hardy-Weinberg equilibrium. Isomogowati and Purwantini (2010) reported that all the six loci used in the study deviated from Hardy-Weinberg equilibrium in local Indonesian ducks due to selection and migration in the three duck population. Most duck studies cited above indicated that most loci studied were in Hardy-

Weinberg equilibrium attesting to the genetic stability of the studied populations and lack of evolutionary forces that causes loci to deviate from Hardy-Weinberg equilibrium.

CHAPTER 3

Growth Performance of Muscovy and Pekin Ducks under Intensive Management System in Botswana

Abstract

The purpose of the study was to compare growth performance of Muscovy and Pekin ducks under an intensive management system in Botswana. A total of 64 Muscovy and 64 Pekin ducks were raised from day old to 16 weeks of age under deep litter management system. A total of eight randomly selected Muscovy and 8 randomly selected Pekin ducks were housed in separate rearing units for a total of 8 rearing units resulting in 8 replications per breed. The birds were fed commercial broiler starter crumbs for the first two weeks of life and broiler grower pellets thereafter until 16 weeks of age. Feed and water were provided ad libitum. Body weight of individual ducks were taken weekly from 3 to 16 weeks of age. Muscovy and Pekin ducks of both sexes had the most rapid growth rate during the first 7 weeks of life. Pekin ducks had significantly higher feed intake (P<0.05) than their age-matched Muscovy counterparts from 3 weeks (436.63±7.37 vs. 298.54±7.37g, respectively) to 13 weeks (473.22±1.77 vs. 467.56±1.77g, respectively) of age. Muscovy ducks however had significantly better feed conversion efficiency than Pekin ducks from 6 weeks (10.38±0.03 vs. 16.46±0.03) to 16 weeks (58.96±0.92 vs. -159.59 ± 0.92) of age. Male Pekin ducks were significantly heavier (p<0.05) than their age-matched Muscovy counterparts from 3 weeks (770.54 ±19.35 vs. 539.35±19.35g) to 6 weeks (2478.36 ±55.31 vs. 1638.84 ±55.31g, respectively) of age. There were no significant differences in body weight between the two breeds from 7 weeks (2768.48±32.84 vs. 2730.54±32.84g) to 11 weeks (3295.58±40.11 vs. 3382.63±40.11g) of age. Male Muscovy ducks were however, significantly heavier than Pekin males from 12 weeks (3507.95±38.79 vs. 3311.60±38.79g) to 16 weeks (4051.56 ±37.66 vs. 3192.00±37.07g) of age. Pekin females were significantly heavier (P<0.05) than their age-matched Muscovy counterparts at all ages from 3 (710.10±19.35 vs. 363.48 ±19.35g, respectively) to 16 weeks (2714.89 ±37.07 vs. 1991.51±37.07g, respectively) of age. Early enhanced growth performance of Pekin ducks (both males and females) compared to Muscovy ducks make them more suitable candidates for selection of meat type ducks.

Key words: body weight, duck, intensive management, Muscovy and Pekin

3.1 INTRODUCTION

Duck farming and production has received much attention because of the steady increase in duck meat consumption (El-Gendy, 2005). Ducks are primarily raised for meat, eggs and feathers. According to Moreki (2011), Botswana imports most of its duck meat from South Africa. These imports were over 2 tons of duck meat annually from the year 2006 (Moreki, 2011). Intensive duck farming in Botswana present an avenue for the diversification of the poultry industry to meet local demand for duck meat and for possible export to duck meat markets in Asian countries (Adzitey, 2012). Ducks are less exigent for feed quality and less susceptible to diseases than chicken (Modak, 1996 as cited by Bhuiyan *et al.*, 2005) and their intensive production could be a rapid solution to protein shortage in Africa. Ducks are less susceptible to common poultry diseases such as leucosis, Marek's disease, infectious bronchitis and other respiratory disorders (Sari *et al.*, 2013). Ducks are also able to adapt to a wide range of environmental and natural conditions, which may be the reason for their increasing importance and popularity (Solomon *et al., 2006)*.

Intensive breeding and selection of ducks have resulted in the production of duck breeds and strains with desirable traits and growth performance. Duck breeds available for intensive production in Botswana include the Muscovy and White Pekin ducks. Pekin ducks have been reported to outpace the modern broiler chicken in terms of body weight gain and feed efficiency to the same live weight due to genetic improvement (Zhou, 2011). Considerable information is available on the growth performance of Pekin and Muscovy ducks under different production systems in other parts of the world but their growth performance under Botswana local weather conditions has never been evaluated. Therefore, the objective of this study was to evaluate the growth performance of the Muscovy and Pekin duck fed commercial broiler diets under intensive management system in southeastern Botswana.

3.2 MATERIALS AND METHODS

3.2.1 Study area

The study was carried out in Botswana University of Agriculture and Natural Resources, Content Farm, Sebele, Gaborone, in the South-eastern part of Botswana. The study commenced in December 2014 and ended in March 2015. During the study period, environmental temperature averaged 31.0°C (ranged between 17.2 and 38.2°C).

3.2.2 Experimental birds and their management

Prior to the start of the experiment, sixty-four (64) Pekin ducklings and sixty-four (64) Muscovy day old ducklings were bought from duck producers in Gaborone city and surrounding villages. The ducklings were then raised in separate well-ventilated brooding unit for two weeks. Ducklings were individually identified at 3 weeks of age using leg bands and then 8 randomly selected Muscovy and 8 randomly selected Pekin ducks were housed in separate pens (measuring an area of $16m^2$) according to breed for a total of 8 pens per breed, resulting in 8 replications per breed. Ducklings were vaccinated against Newcastle disease and Gumboro (infectious bursal disease) at 28 and 30 days of age, respectively. Birds were raised under natural light throughout the study period.

Ducklings were provided with chick broiler starter crumbs from day old to 2 weeks of age and broiler grower pellets from 3 to 16 weeks of age (Table 3.1). Commercial broiler diets were obtained from one supplier in Gaborone. Feed and water were provided *ad libitum* throughout the experimental period. The nutritional composition of broiler chick starter crumbs and broiler grower pellets fed to ducklings is shown on Table 3.1.

Table 3.1 Nutrient composition of broiler starter and grower diets fed to experimental birds.

Composition	Chick starter (g/kg) (0 -3 weeks of age)	Grower pellets (g/kg) (3 – 16 weeks of age)
Protein	200	180
Moisture	120	120
Fibre	50	60
Calcium	8	7
Fat	25	25
phosphorous	6	5.5
Lysine	12	10

3.2.3 Measurement of growth performance, feed intake and feed efficiency

Body weight was recorded on a weekly basis from 3 weeks to 16 weeks of age using an electronic balance. Daily feed intake was determined by giving pre-weighed feed allocations to each replicate group in the morning and unconsumed feed was weighed back the morning of the following day. Daily fed intake per bird was calculated by dividing daily feed intake of the replicate group by the number of ducklings per replicate. Feed conversion ratio (FCR) was calculated according to Safalaoh (2006).

3.2.4 Experimental Design and Statistical analysis

The experiment was set up as a completely randomized design with two experimental treatments (Muscovy breed and Pekin breed) and eight replications per treatment. Growth data were analyzed using Mixed Models Procedures of SAS version 9.2.1 (2009). The model fitted included the fixed effects of breed (Muscovy and Pekin), sex (male and female) and the interaction between the two fixed factors (sex x breed). Feed intake and feed efficiency data were analyzed using Mixed Models Procedures of SAS version 9.2.1 (2009) and the model included the fixed effects of breed (Muscovy and Pekin). Body weight, feed intake and feed efficiency results are presented as least squares means ± standard error. Least square means separation was by paired t-test and differences between means were significantly different at $P \leq 0.05$.

Statistical model used in the analysis of growth data:

$Y_{ijk} = \mu + T_i + S_j + (T_i*S_j) + e_{ijk}$

Where: Y_{ijk} = observation variable

μ = population mean

T_i = treatment (breed) effects; i = Muscovy or Pekin ducks

S_j = sex effects; j = male or female

T_i*S_j = interaction of breed and sex effects

e_{ijk} = residual / random error ~N $(0, \sigma^2)$.

3.3 RESULTS AND DISCUSSION

Body weights of Muscovy and Pekin ducks of both sexes from week 3 weeks to 16 weeks of age are shown in Fig 3.1. Male Pekin ducks were significantly heavier ($p<0.05$) than their age-matched Muscovy counterparts from 3 weeks (770.54±19.35 vs. 539.35±19.35g, respectively) to 6 weeks (2478.36±55.31 vs. 1638.84±55.31g, respectively) of age. There were no significant differences in body weight between male Pekin and male Muscovy ducks from 7 weeks (2768.48±32.84 vs. 2730.54±32.84g, respectively) to 11 weeks (3295.58±40.11 vs. 3382.63±40.11g, respectively) of age. Male Muscovy ducks were however, significantly heavier than Pekin males from 12 weeks (3507.95±38.79 vs. 3311.60±38.79g, respectively) to 16 weeks (4051.56 ±37.66 vs. 3192.00±37.07g, respectively) of age. Early enhanced growth performance, from 3 to 6 weeks of age, in Pekin than Muscovy males observed in the current study is consistent with Damaziak *et al.* (2013) who also reported higher body weights in Pekin than Muscovy males from 3 weeks to 6 weeks of age. Tai and Rouvier (1998) also reported significantly higher body weight in Pekin than Muscovy males (1045±92 and 915±106g, respectively) at 4 weeks of age. Similar body weights between Muscovy and Pekin males at 10 weeks of age are consistent with Omojola (2007) and Galal *et al.* (2011). To the contrary, Tai and Rouvier (1998) reported significantly higher body weight in Muscovy than Pekin males at 10 weeks of age (3550±321 and 2630±232g, respectively). Significantly higher body weight in Muscovy than Pekin males at 16 weeks of age found in this study is however consistent with Tai and Rouvier (1998) who reported body weights of 4918±364 and 3005±254g in Muscovy and Pekin males, respectively. Although at the end of the study Muscovy males were significantly heavier than their Pekin counterparts, early enhanced growth performance (from 3-6 weeks of age) in Pekin than Muscovy males make Pekin ducks more suitable candidates for possible selection of broiler or meat type ducks than Muscovy ducks.

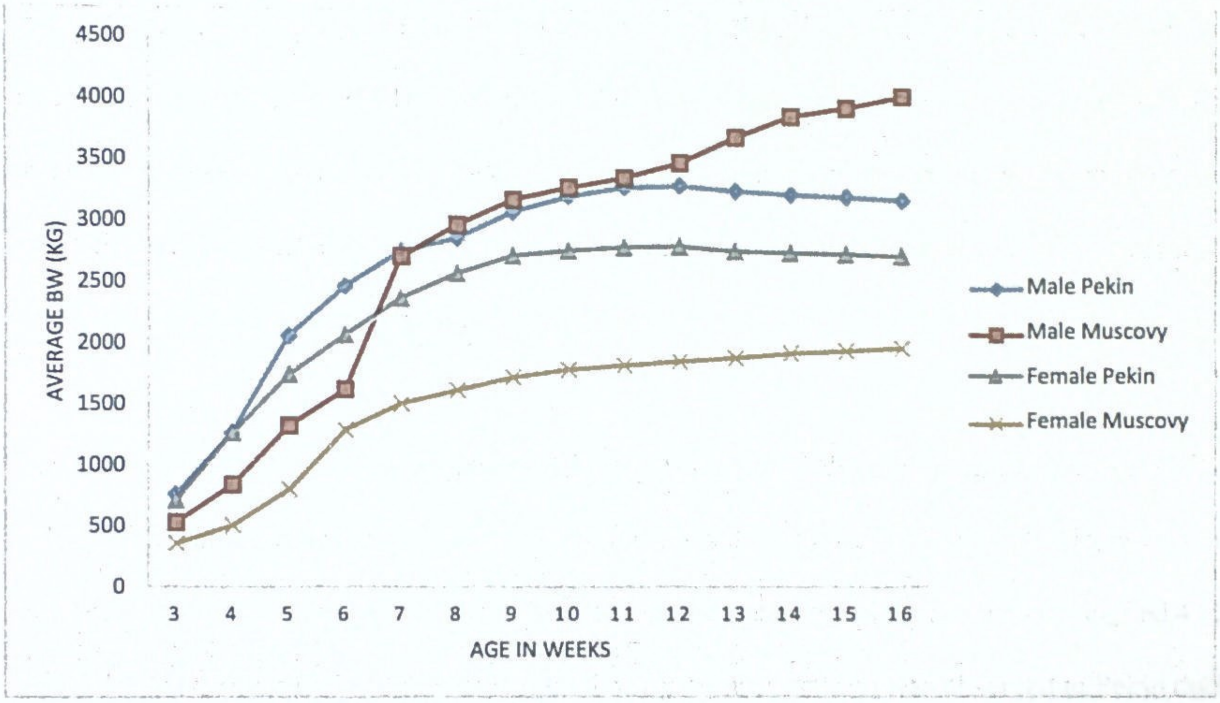

Fig. 3.1: Sexual dimorphism in body weights of Muscovy and Pekin ducks from 3 to 16 weeks of age

Pekin females were significantly heavier ($P<0.05$) than their age-matched Muscovy counterparts at all ages from 3 weeks (710.10±19.35 vs. 363.48 ±19.35g, respectively) to 16 weeks (2714.89 ±37.07 vs. 1991.51±37.07g, respectively) of age (Fig 3.1). Significantly higher body weight in Pekin than Muscovy females from 3 to 16 weeks of age is consistent with Swatland (1979) who reported higher body weight in white Pekin than white Muscovy females from day old to 10 weeks of age. Solomon (2006) and Damaziak *et al*. (2013) also reported significantly higher body weights in Pekin than Muscovy females from 3 weeks (650 vs. 580g, respectively) to 7 weeks (1900 vs. 1760g, respecrively) weeks of age. To the contrary Galal *et al*. (2011) and Tai and Rouvier (1998) reported significantly higher body weight in Muscovy than Pekin females at 10 weeks (2467±71.14 vs. 2015±71.14g, respectively) and 16 weeks (2812±234 vs. 2712±23g, respectively) of age, respectively. Omojola (2007) also reported significantly higher body weight in Muscovy than Pekin females (1583.30±169.69 vs. 1466.70±169.69g, respectively) at 10 weeks which might be caused by a decline in feed intake by Pekin ducks which normally occurs during molting. Just like their male counterparts, female Pekin are therefore more suitable candidates for utilization as broiler-type duck than Muscovy females.

The main effects of breed of duck (combined weights of both males and females of each breed) on body weight and average daily gain at different ages are shown in table 3.2. There was no significant difference in the day-old weight of Pekin and Muscovy ducklings which weighed 47.25 and 47.34g, respectively. Significantly higher body weight ($P < 0.05$) was observed in Pekin ducks than their age-matched Muscovy counterparts from 3 weeks (740.32±19.35 vs. 451.42±19.3g, respectively) to 13 weeks (3012.45±37.57 vs. 2813.71±37.57g, respectively) of age. There was no significant difference in body weight between Pekin and Muscovy ducks from 14 (2991.15±36.55 vs. 2918.11±36.55g, respectively) to 16 weeks (2953.45±37.07 vs. 3021.54±37.07g, respectively) of age. Significantly higher body weight in Pekin than Muscovy ducks at 3 to 13 weeks of ages is consistent with St Eczny *et al.* (2015) who reported significantly higher body weight in Pekin than Muscovy ducks from 3 weeks (1241±4.8 vs. 781±4.1g, respectively) to 8 weeks (3401±15.8 vs. 3246±98.5g, respectively) of age. Bhuiyan *et al.* (2005) also reported higher body weight in Pekin than Muscovy from 1 week (152 vs. 106g, respectively) to nine weeks of age (1763 vs. 1225g, respectively). Contrary to the current findings, Rashid *et al.* (2009) reported no significant differences in body weights between Pekin and Muscovy ducks from 1 week to 6 weeks of age and significantly higher body weight in Muscovy than Pekin ducks from 6 (790 vs. 700g, respectively) to 10 (1280 vs. 1100g, respectively) weeks of age. Galal *et al.* (2011) also reported significantly higher live weight in Muscovy than Pekin ducks (3007 vs. 2321g) at 10 weeks of age.

Average daily gains differed significantly between Muscovy and Pekin ducks at all ages from 4 (33.09±0.08 vs. 66.52±0.08g, respectively) to 16 (8.11±0.01 vs. -2.96±0.01g, respectively) weeks of age except at 10 weeks of age where Muscovy and Pekin ducks had similar average daily gains (12.19±0.09 vs. 12.44±0.09g) (Table 3.2). Pekin ducks had significantly higher average daily gain than Muscovy ducks up to 5 weeks (100.06±0.91 vs. 56.33±0.91g at 5 weeks of age, respectively) of age. Pekin ducks had earlier enhanced average daily gains than Muscovy ducks with maximum average daily gain occurring at 5 weeks of age in Pekin and at 7 weeks of age in Muscovy ducks. Early enhanced average daily gains in Pekin than Muscovy ducks is consistent with Wielderhold and Pingel (1997) who also found that Pekin ducks have maximum growth rate earlier than Muscovy ducks. There was no significant difference in average daily gain between Muscovy and Pekin ducks at 10 weeks of age (12.19 vs. 12.44 g/duck/day, respectively) but thereafter Muscovy ducks had significantly higher average daily gains than their Pekin counterparts up to 16 weeks of age. In fact, Pekin ducks had negative average daily gains from 13 to 16 weeks of age while Muscovy ducks had positive average daily gains throughout the study period. Negative average daily gains in Pekins ducks from 13 to 16 weeks of age is consistent with Hashimoto and Sugimura (1976) who reported lower body weight at 13 weeks (2066.0±366.0g) and 17 weeks (2150.0±273.0g) weeks of age than at 11 weeks of age (2300.0±291.2g) of age. According to Woynarovich (1982), Pekin ducks grow fast and reach market weight within 50-56 days of age and thereafter first molting occurs and growth practically stops resulting in loss of body weight and negative average

Table 3.2: Main effects of breeds on body weights of ducks at various ages raised under an intensive management system.

Age in weeks	Average body weight (g)		Average daily gain (g/bird/day)	
	Muscovy	Pekin	Muscovy	Pekin
3	451.42^{b}±19.35	740.32^{a}±19.35	-	-
4	683.07b±31.48	1205.99^{a}±31.48	33.09^{b}±0.08	66.52^{a}±0.08
5	1077.40^{b}±34.16	1906.42^{a}±34.16	56.33^{b}±0.91	100.06^{a}±0.91
6	1472.62^{b}±55.31	2272.33^{a}±55.31	56.46^{a}±0.01	52.27^{b}±0.01
7	2128.82^{b}±32.84	2567.44^{a}±32.84	93.74^{a}±1.84	42.16^{b}±1.84
8	2313.88^{b}±37.09	2722.72^{a}±37.09	26.44^{a}±0.25	22.18^{b}±0.25
9	2470.35^{b}±37.70	2903.67^{a}±37.70	22.35^{b}±0.05	25.85^{a}±0.05
10	2555.74^{b}±41.40	2990.47^{a}±41.40	12.19±0.09	12.44±0.09
11	2615.49^{b}±40.11	3041.09^{a}±40.11	8.54^{a}±0.02	7.23^{b}±0.02
12	2694.96^{b}±38.79	3053.54^{a}±38.79	11.35^{a}±0.01	1.78^{b}±0.01
13	2813.71^{b}±37.57	3012.45^{a}±37.57	16.96^{a}±0.02	-5.87^{b}±0.02
14	2918.11±36.55	2991.15±36.55	14.91^{a}±0.01	-3.04^{b}±0.01
15	2964.80±37.09	2974.20±37.09	6.67^{a}±0.40	-2.42^{b}±0.40
16	3021.54±37.07	2953.45±37.07	8.11^{a}±0.01	-2.96^{b}±0.01

daily gains. Several studies reported weight loss during molting in various bird species and attributed the weight loss to the utilization of stored lipids during molting, hence the weight loss

(Hanson and Jones, 1976; Owen and Ogilvie, 1981; Geldenhuys, 1983).The average daily gains of both Muscovy and Pekin ducks throughout the study period support Tai and Rouvier (1998) who found that the direct genetic effects for growth from autosomal and sex-linked genes were in favor of Pekin at 4 weeks of age (early in life) and in favor of the Muscovy from 10 to 40 weeks of age (late in life).

Feed intake of Pekin ducks was significantly higher than that of Muscovy ducks from 3 weeks (436.63±7.37 vs. 298.54±7.37g, respectively) to 13 weeks (473.22±1.77 vs. 467.56±1.77g, respectively) of age (table 3.3). Thereafter there was no significant difference in feed intake between Pekin and Muscovy ducks up to 16 weeks (472.39±2.04 vs. 478.14±2.04) of age. Significantly higher feed intake in Pekin than Muscovy ducks up to 13 weeks of age is consistent with Bhuiyan *et al.* (2005) who also reported significantly higher feed consumption in Pekin than Muscovy ducks at all ages from 1 week (313.12 vs. 244.8 g/duckling/week) to 9 weeks of age (4409 vs. 3608 g/duckling/day). Rashid *et al.* (2009) reported almost similar feed consumption between Muscovy and Pekin ducks but comparatively higher feed consumption in Pekin than Muscovy ducks at all ages up to 10 weeks of age. Feed intake of Pekin ducks remained relatively constant from 13 weeks (473.22±1.77) to 16 (472.39±2.04) weeks of age and were lower than the feed intake at 12 (660.80±3.42) weeks of age which might be attributed to a decline in feed intake which normally occurs at molting. Hartman (1985) reported a reduction in feed intake in ducks during molting compared to pre-molting period.

Feed Conversion ratio differed significantly between Muscovy and Pekin ducks at all ages from 4 to 16 weeks of age (Table 3.3). Pekin ducks had significantly better feed conversion efficiency than their age-matched Muscovy counterparts up to 5 weeks of age (7.24±0.10 vs. 9.23±0.10 at 5 weeks of age, respectively). Thereafter Muscovy ducks had significantly better feed conversion efficiency than their Pekin counterparts from 6 weeks (10.38±0.03 vs. 16.46±0.03) to 16 weeks (58.96±0.92 vs. -159.59±0.92) of age. Pekin ducks had negative feed conversion efficiency from 13 (-80.62±0.39) to 16 (-159.59±0.92) weeks of age. The negative feed conversion efficiency during that period is attributable to the continued feed consumption and weight losses during the same period because of molting. Higher feed conversion efficiency in Muscovy than Pekin ducks from 6 to 16 weeks of age found in the current study is consistent with Rashid *et al.* (2009) who also found significantly higher feed conversion efficiency in Muscovy than Pekin ducks from 5 weeks (2.5 vs. 3.0, respectively) to 10 weeks (3.2 vs. 3.6, respectively). Galal *et al.* (2011) also reported significantly higher feed conversion efficiency in Muscovy than Pekin ducks at 10 weeks (2.37 and 2.48, respectively). Contrary to the current findings Bhuiyan *et al.* (2005) reported significantly higher feed conversion efficiency in Pekin than Muscovy ducks at all ages from 1 week to 9 weeks of age.

Table 3.3: Main effects of breeds on average daily feed intake (g/day/bird) and feed conversion ratio at different ages

AGE IN WEEKS.	FEEDINTAKE g/day/bird		FEED CONVERSION RATIO	
	Muscovy	Pekin	Muscovy	Pekin
3	298.54^{b}±7.37	436.63^{a} ±7.37	-	-
4	454.82^{b}±5.92	591.14^{a} ±5.92	13.74^{a}±0.08	8.89^{b} ± 0.08
5	519.85^{b}±5.03	725.04^{a} ±5.03	9.23^{a} ± 0.10	7.24^{b} ± 0.10
6	586.23^{b}±2.41	860.12^{a} ±2.41	10.38^{b} ± 0.03	16.46^{a} ± 0.03
7	655.62^{b}±4.40	1001.23^{a} ±4.40	6.99^{b} ± 0.28	23.75^{a} ± 0.28
8	719.35^{b}±2.84	968.23^{a} ±2.84	27.21^{b} ± 0.32	43.65^{a} ± 0.32
9	651.57^{b}±3.62	876.63^{a} ±3.62	29.15^{b} ± 0.17	33.91^{a} ± 0.17
10	669.49^{b}±2.36	800.37^{a} ±2.36	54.92^{b} ± 0.55	64.34^{a} ± 0.55
11	526.85^{b}±3.03	637.82^{a} ±3.03	61.54^{b} ± 0.85	88.22^{a} ± 2.12
12	495.32^{b}±3.42	660.80^{a} ±3.42	43.64^{b} ± 2.12	371.24^{a} ± 0.28
13	467.56^{b}±1.77	473.22^{a} ±1.77	27.57^{b} ± 0.28	-80.62^{a}± 0.39
14	473.02±1.67	472.51±1.67	31.73^{b} ± 0.39	-155.43^{a} ± 26
15	473.11±1.71	472.31±1.71	70.92^{b} ± 26.09	-195.17^{a} ±26.1
16	478.14±2.04	472.39±2.04	58.96^{b} ± 0.92	-159.59^{a}± 0.92

Means with different superscripts between breeds at a particular age were significantly different at ($P<0.005$)

3.4 CONCLUSIONS

-Pekin duck females had superior growth performance at all ages compared to Muscovy duck females.

-Muscovy males had higher body weights than pekin males from 8 weeks to 16 weeks of age.

- Pekin ducks had higher feed consumption as compared to Muscovy ducks

-Muscovy ducks had relatively better feed conversion efficiency than Pekin ducks

CHAPTER 4

ASSESSMENT OF GENETIC DIVERSITY OF MUSCOVY DUCK POPULATION IN BOTSWANA USING MICROSATELLITE MARKERS

Abstract

The purpose of the study was to evaluate the genetic diversity of Muscovy (Cairina moschata domestica) ducks around Gaborone city and surrounding villages using a panel of 13 chicken microsatellite markers. Twenty-five blood samples of Muscovy ducks from distinct locations in and around Gaborone were obtained and genotyped using a panel of FAO recommended chicken microsatellite markers. Eight out of a total of thirteen markers amplified successfully and were used for the assessment of genetic diversity in Muscovy. Observed and effective number of alleles ranged between 5 and 12 and between 2.495 and 5.189, respectively. The mean observed and effective numbers of alleles in Muscovy were 8.25 and 3.66, respectively. The observed heterozygosity ranged between 0.435 and 0.913 with mean observed heterozygosity of 0.733± 0.164, while the expected heterozygosity ranged between 0.613 and 0.825 with mean expected heterozygosity of 0.725±0.078. The mean observed and mean expected number of alleles per marker all translated to high levels of genetic diversity in Muscovy. All the eight loci studied were in Hardy-Weinberg equilibrium indicating high genetic stability in Muscovy. The inbreeding coefficient of the Muscovy population was -0.136 indicating an excess of heterozygotes in the population and therefore, negligible levels of inbreeding in the Muscovy population. High levels of genetic diversity exist within the Muscovy population in Botswana as indicated by high allelic diversity and high average expected heterozygosity. The Muscovy populations is outbred and therefore, possess sufficient genetic variation for genetic improvement and to withstand anticipated environmental changes resulting from global warming and climate change.

Key words: Botswana, Chicken Microsatellite, Genetic Diversity, Muscovy ducks

4.1 INTRODUCTION

Indigenous animal genetic resources play a pivotal role in the livelihoods of the majority of the rural populace through the provision of food and income and are mostly kept under the low input low output free ranging management systems (FAO, 1998). Notable attributes of indigenous animal genetic resources include disease resistance, high fertility, parasite and heat tolerance and ability to utilize low quality feeds and this lead to increase in food supply and security (Yakubu, 2013). Poultry genetic resources in general are considered to be the most endangered and under-conserved and strategic approaches to conservation at the national level need to be developed and implemented (Hoffmann, 2009). Indigenous poultry have innate potential to produce eggs and meat at considerable quantity with lesser input and they are a good dietary source of protein and therefore, serve as a means of providing additional income to the generally resource-poor small holder farmers (Gueye, 2004 and Veeramani, 2014).

Animal genetic resources (AnGRs) in developing countries in general, are being eroded through indiscriminate introduction of exotic genetic resources before proper characterization, utilization and conservation of indigenous genetic resources (Yakubu *et al.*, 2011). Ducks in Africa have been morphologically characterized (Teguia *et al.*, 2008) using both univariate and multivariate discriminant analysis. However, the accuracy of phenotypic characterization of domestic animals is often affected by the influence of the environment and the underlying genetic complexity (Yakubu *et al.*, 2011).

The Muscovy duck has traditionally been kept by small-scale farmers in different parts of Botswana and is well-adapted to the low input-low output production environment of resource-poor farmers. However, in recent past, the country has seen an influx of the fast-growing and highly productive Pekin ducks from China which threaten the genetic diversity of the Muscovy through indiscriminate crossbreeding. The objective of this study was therefore to assess the genetic diversity of the Muscovy duck population in Botswana and to provide baseline data for future monitoring of genetic diversity trends and to inform future conservation and management decisions.

4.2 MATERIALS AND METHODS

4.2.1 Blood sample collection

Blood samples were collected from the brachial vein of 25 unrelated Muscovy ducks using vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA). Blood samples were collected from individual Muscovy ducks in Gaborone (n=4) and surrounding villages [Odi (n=3), Modipane (n=3), Kumakwane (n=3), Mogobane (n=3), Gabane (n=3), Kopong (n=3), Mmopane (n=3)]. Immediately after collection blood samples were stored under ice in the field and later transferred to a freezer maintained -20°C until DNA extraction.

4.2.2 DNA extraction

Total genomic DNA was extracted from blood samples using Zymo quick_gDNA Mini Prep kit (Zymo Research Corporation, CA, U.S.A.) following the manufacturer's protocol with some minor modifications. 5µl of whole blood was transferred into 1.5ml microcentrifuge tube and 200µl of digestion buffer and 20µl proteinase K were added to whole blood and mixed by vortexing for 5-15 seconds. 200µl of cell lysis buffer was then added and mixed by vortexing for 5-15 seconds. The samples were then incubated at 50°C for 10 minutes. After incubation, 200µl of cold 100% ethanol was added to each sample and mixed by vortexing for 5-15 seconds before being transferred to a Zymo-spin™ column placed in a collection tube. Zymo-spin™ column was then centrifuged at 8 000 x g for one minute and the collection tube with the flow through was discarded.

The Zymo-spin™ was then transferred to a new collection tube and 400 µl of DNA Pre-wash buffer was added to the spin column and centrifuged at 8 000 x gravity for one minute and the collection tube with the flow through was discarded. 500 µl of g-DNA wash buffer was added to the spin column and centrifuged at 14 000 x g for three minutes. The spin column was then transferred to a clean micro centrifuge tube and 200 µl of DNA Elution buffer was added to the spin column and incubated for 5minutes at room temperature before being centrifuged at 8000 x g for 1 minute to elute the DNA. The extracted gDNA was later used for polymerase chain reaction and DNA typing.

4.2.3 Primers and Polymerase Chain Reaction (PCR)

A panel of 8 FAO recommended chicken primers pairs were used for selective amplification of 8 microsatellite markers in Muscovy ducks. The microsatellite markers, their chromosomal positions, size range and primers used for their amplification are shown in Table 4.1

Table 4.1: Microsatellite marker information and primers used for amplification of the Markers

Name	Chromosome	Primer sequence (5' -> 3') Forward Reverse	Annealing temperature (°C)	Allele range (bp)
ADL0268	1	CTCCACCCCTCTCAGAACTA CAACTTCCCATCTACCTACT	60	102-116
MCW0081	5	GTTGCTGAGAGCCTGGTGCAG CCTGTATGTGGAATTACTTCTC	60	112-135
MCW0165	23	CAGACATGCATGCCCAGATGA GATCCAGTCCTGCAGGCTGC	60	114-118
MCW0248	1	GTTGTTCAAAAGAAGATGCATG TTGCATTAACTGGGCACTTTC	60	205-225
MCW0111	1	GCTCCATGTGAAGTGGTTTA ATGTCCACTTGTCAATGATG	60	96-120
MCW0216	13	GGGTTTTACAGGATGGGACG AGTTTCACTCCCAGGGCTCG	60	139-149
LEI0234	2	ATGCATCAGATTGGTATTCAA CGTGGCTGTGAACAAATATG	60	216-364
MCW0103	3	AACTGCGTTGAGAGTGAATGC TTTCCTAACTGGATGCTTCTG		266-270
MCW020	1	TCTTCTTTGACATGAATTGGCA GCAAGGAAGATTTTGTACAAAATC	60	179-188
LEI0094	4	GATCTCACCAGTATGAGCTGC TCTCACACTGTAACACAGTGC	60	247-287
MCW0284	4	GCCTTAGGAAAAACTCCTAAGG CAGAGCTGGATTGGTGTCAAG	60	235-243
MCW0078	5	CCACACGGAGAGGAGAAGGTCT TAGCATATGAGTGTACTGAGCTTC	60	135-147
ADL0112	10	GGCTTAAGCTGACCCATTAT ATCTCAAATGTAATGCGTGC	58	120-134

Source: ISAQ-FAO recommended microsatellite markers (2011)

Selective amplification of different microsatellites was achieved through polymerase chain reaction (PCR) using thermocycler GeneAmp PCR System 9700 (Applied Biosystems, Forester

City CA, USA) and PCR reagents synthesized by Fermentas Life Sciences (Opelstrasse, Germany). All loci were amplified individually in a 20 μl reaction volume comprising 2μl of 10x PCR buffer, 2ul of 25mmol $MgCl_2$, 0.8ul of 10 pmol/ul each primer and 90 ng of Muscovy duck genomic DNA. The PCR cycling conditions for selective amplification of the microsatellite markers were according to Mukesh *et al.* (2011).

4.2.4 Microsatellite Genotyping

The resulting microsatellite marker amplicons were diluted by mixing 1ul of PCR product with 9ul nuclease free water. The diluted PCR product was then mixed with 8.7ul hide formamide and 0.3ul genescan LIZ-500. The resulting mixture was denatured by heating in a thermal cycler at 95°C for 5minutes followed by immediate storage under ice. The PCR products were then separated using capillary electrophoresis ABI Prism 310 Genetic Analyzer (Applied Biosystems, Foster city, CA, USA). Data on fragment size were analysed automatically using Genescan Analysis Software v.3.1 which provided information on allele size using genescan Liz-500 as the internal size standard and Genotyper 2.5 identified different alleles for each marker.

4.2.5 *Data analysis for polymorphic microsatellite markers*

The observed number of alleles (Na), effective population size (Ne), observed (Ho) and expected heterozygosity (He) estimates and Inbreeding coefficient (Fis) were computed after Nei (1973), as executed in POPGENE Software (Yeh *et al.*, 1999). The polymorphic information content (PIC) of each marker was calculated with Cervus (ver 3.0) computer programme (Kalinowski *et al.*, 2007). The expected number of genotypes was compared with the observed genotypes in a chi-square test for goodness of fit to assess whether each marker was in Hardy-Weinberg equilibrium using POPGEN 3.

4.3 RESULTS AND DISCUSSION

4.3.1 Observed and Effective number of alleles

A total of 66 alleles were observed across all the 8 loci in Muscovy ducks (Table 4. 2). All the eight microsatellite markers were polymorphic and the number of observed alleles per marker ranged between 5 (MCW0103) and 12 (LEI0234), with overall mean observed number of alleles per locus of 8.250. The mean observed number of alleles per locus of 8.250 found in Muscovy duck population of Botswana indicates high allelic diversity probably due to lack of artificial selection by farmers and avoidance of inbreeding. All the markers used in the study are also suitable for genetic diversity studies as a minimum of four alleles per marker are recommended for effective screening of genetic differences within and between as suggested by Pandey *et al.* (2006).

Table 4.2 Observed and effective number of alleles per marker in Muscovy ducks

Marker	Alleles (bp)	Na	Ne
MCW0248	97,100,111,113,115,117	6	2.899
MCW0081	108,110,112, 116,120,124,126,128,130,134,136	11	4.766
LEI0234	104,128,209,220,240,246,248,260,360,364,378,380	12	5.189
MCW0111	120,125,128,130,135,140,146,149	8	2.874
ADL0248	210,236,238,240,242, 244	6	2.939
MCW0103	240,261,265,271, 273	5	2.495
MCW0165	110,112,114,116,118,120,130,132	8	4.133
MCW0216	128,132,134,135,138,140,143,144,146,154	10	3.977
Mean		8.250±2.550	3.659±0.997

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

The range of observed alleles per marker and mean number of alleles per marker observed in this study are comparable to a range of 5 to 13 alleles per marker and mean number of alleles per marker of 8.428 found in Chinese native ducks (Li *et al.*, 2006). The mean observed number of alleles per marker found in this study is also similar to the mean observed number of alleles per marker of 8.33 reported by Wu *et al.* (2009) in Beijing ducks. Hui- Fang *et al.* (2010) reported a slightly lower range of 3 to 10 observed number of alleles per marker and mean observed number of alleles per marker of 6.1 in indigenous Chinese egg-type ducks. The mean number of observed alleles per marker found in the current study is higher than the mean observed number of alleles per marker of 6.167, 3.1 and 2.44 reported in Indonesian local ducks, Chinese ducks and Muscovy ducks, respectively (Ismogowati and Purwantini, 2010; Li *et al.*, 2006; Ahmadi *et al.*, 2007). The mean observed number of alleles per marker found in this study is however lower than 10.058, 12.2, 9.38, 11.29 found in indigenous Indian ducks, Chinese indigenous laying type ducks, South and East Asian ducks and Coastal ducks, respectively (Mukesh *et al.*, 2011; Su and Chen, 2009; Seo *et al.*, 2016; Gaur *et al.*, 2016).

The effective number of alleles per marker for all the eight markers were smaller than the observed number of alleles and ranged between 2.537 (MCW0103) and 4.766 (MCW0081) with mean effective number of alleles per marker of 3.659. The mean effective number of alleles per marker observed in this study is similar to 3.37 and 4.26 reported in Chinese laying egg type and land and Coastal ducks, respectively (Hui Fang *et al.*, 2010; Gaur *et al.*, 2016). The mean effective number of alleles per marker of Muscovy ducks found in this study is lower than the mean effective number of alleles per marker of 4.67, 4.8 and 5.141 reported in indigenous Indian ducks, Chinese native duck breeds and Chinese egg laying type ducks, respectively (Mukesh *et al.*, 2011; Li *et al.*, 2006; Hui Fang *et al.*, 2010) respectively. The mean effective number of alleles per marker found in the current study is however higher than the mean effective number of alleles per marker of 1.7 and 2.03 found in Pekin ducks and Chinese indigenous laying type ducks, respectively (Khan Ahmadi, 2007; Su and Chen, 2009). The relatively higher number of alleles in our local Muscovy ducks as compared to Pekin and Chinese indigenous laying type ducks might indicate that the effects of isolation, inbreeding and selection have been mild on the local Muscovy duck.

4.3.2. Other Measures of Genetic Diversity

The observed and expected heterozygosity, polymorphism information content and inbreeding coefficients are shown in Table 4.3. The observed heterozygosity of Muscovy ducks ranged between 0.435 (ADL0268) and 0.913 (MCW0216) with average observed heterozygosity over all loci of 0.733±0.164. The average observed heterozygosity in Muscovy ducks (0.733±0.164) is comparable to the average observed heterozygosity of 0.693 found in Chinese indigenous laying type ducks using a panel of 17 microsatellite markers (Su and Chen, 2009). Lower average observed heterozygosity values of 0.44, 0.492, 0.496 and 0.514 were reported in Muscovy ducks, South and East Asian ducks, Chinese indigenous ducks and Beijing ducks, respectively (Khan Ahmadi, 2007; Seo *et al.*, 2016; Liu *et al.*, 2008; Wu *et al.*, 2009). The average observed heterozygosity of Muscovy ducks in Botswana is however lower than average observed heterozygosity of 0.862 found in indigenous egg type duck breeds assessed using a panel of 29 microsatellite markers (Hui-Fang *et al.*, 2010). The expected heterozygosity was lower than the observed heterozygosity indicating excess heterozygotes in the population and ranged between 0.613 (MCW0103) and 0.808 (MCW0081) with mean expected heterozygosity across all eight loci of 0.725±0.078. For markers to be useful in measuring genetic variation they should have average heterozygosity between 0.3 and 0.8 (Takezaki *et al.*, 1996). Therefore, all markers used in this study were appropriate for measuring genetic diversity in Muscovy ducks. Expected heterozygosity is considered a more accurate measure of genetic diversity in a population than observed heterozygosity (Nei and Kumar, 2000) and the mean expected heterozygosity of 0.725±0.078 translates to high levels of genetic diversity in Muscovy ducks of Botswana.

The mean expected heterozygosity of Muscovy ducks is comparable with mean expected heterozygosity of 0.72, 0.68 and 0.782 found in indigenous Indian ducks, Land and Coastal ducks and six different duck populations, respectively (Mukesh *et al.*, 2011; Gaur *et al.*, 2016; Wu *et al.*, 2008). Lower mean expected heterozygosity of 0.606 and 0.644 were found in Chinese indigenous ducks and local Indonesian ducks, respectively (Liu *et al.*, 2008, Ismogowati and Purwatini, 2010). More observed heterozygotes in Muscovy duck population than expected is consistent with Ahmadi *et al* (2007) and Hui- Fang *et al* (2010), but contrary to several studies that report a deficiency of heterozygotes in duck populations (Seo *et al.*, 2016; Su and Cheng, 2009; Wu *et al.*, 2009; Gaur *et al.*, 2016) resulting from selective breeding and inbreeding. High mean observed and mean expected heterozygosity in the local Muscovy duck population might be due to avoidance of inbreeding by farmers (exchange of breeding males among farmers) and lack of any selection program aimed at improving traits of economic importance in the local Muscovy ducks.

Table 4.3: Other measures of genetic diversity in Muscovy ducks

Locus	H_o	H_e	PIC	HWE $_{p\text{-value}}$	F_{is}
MCW0248	0.700	0.672	0.655	0.000016	-0.069
MCW0103	0.870	0.619	0.606	0.134	-0.435
MCW0165	0.870	0.775	0.758	0.958	-0.147
ADL0268	0.435	0.674	0.660	0.000	0.3410
MCW0081	0.696	0.808	0.790	0.367	0.120
LEI0234	0.583	0.825	0.807	0.00073	0.227
MCW0111	0.800	0.665	0.652	0.223	-0.223
MCW0216	0.913	0.765	0.749	0.022	-0.220
Mean	0.733±0.164	0.725±0.077	0.710±0750		-0.136

The polymorphic information content (PIC) is another index that measures genetic variation as well as the informativeness or usefulness of a marker in population studies and PIC values range from 0 (no genetic variation and less usefulness of a marker) to 1 (more variation and more usefulness of a marker). Polymorphic information content values of the eight markers used in the current study ranged between 0.606 (MCW0103) and 0.807 (LEI0234) with average PIC value across all loci of 0.710±0.0750 (Table 4.3). The high average PIC value across all loci of 0.710±0.0750 is somehow linked to the high allelic diversity of the individual markers resulting from avoidance of inbreeding and lack of any selection program in local Muscovy ducks. According to Botstein *et al.* (1980) 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. The inbreeding coefficient per locus (F_{is}) ranged between -0.435 (MCW0103) and 0.341 (ADL0268) with a multi-locus inbreeding coefficient of -0.136, which is lower than zero and indicating excess heterozygotes in the Muscovy duck population of Botswana (Table 4.3). All the markers with the exception of ADL0268 contributed to the negative inbreeding coefficient of the Muscovy duck. Only ADL0268 marker 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). Negative population-wise inbreeding coefficient 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 Muscovy duck population. Hui-Fang *et al.* (2010) also reported overall negative inbreeding coefficient in ten Chinese egg-type duck breeds. Several studies involving different breeds/types of ducks however reported positive population-wise inbreeding coefficients (Mukesh *et al.*, 2011; Gaur *et al.*, 2016; Wu *et al.*, 2008; Wu *et al.*, 2009).

All the 8 microsatellite markers used in the current study were tested for Hardy-Weinberg Equilibrium and four of the markers (MCW0111, MCW0081, MCW0165, MCW0103) were in Hardy-Weinberg equilibrium while the other four (MCW248, ADL0268, LEI0234, MCW0216) deviated significantly from Hardy-Weinberg equilibrium (table 4.3). Significant departures of the four markers from Hardy-Weinberg equilibrium could be due to random genetic drift, population stratification or existence of subpopulations within the larger population and non-random mating with respect to the four markers resulting from linkage disequilibrium with some loci undergoing natural selection.

4.4 CONCLUSION

High levels of genetic diversity exist within the Muscovy duck population in Botswana as indicated by high allelic diversity and high average expected heterozygosity. The Muscovy population is also non-inbred and therefore possess sufficient genetic variation to withstand anticipated environmental changes resulting from global warming and climate change and to respond to selective breeding.

CHAPTER 5.

GENERAL DISCUSSION, CONCLUSIONS, RECOMMENDATIONS AND REFERENCES.

5.1. GENERAL DISCUSSION

The purpose of this study was to evaluate growth performance, feed intake and feed conversion ratio of Muscovy and Pekin ducks raised under an intensive management system in Botswana and to assess the genetic diversity of the local Muscovy duck population in Botswana to set baseline data and to inform conservation decisions.

Generally, both Pekin and Muscovy males were significantly heavier ($P<0.05$) than their age-matched female counterparts from 5 to 16 weeks of age. Significantly higher body weights in male than female Muscovy ducks from 5 weeks to 16 weeks of age is consistent with several studies (Teguia *et al.*, 2008; Kleczec *et al.*, 2007; and Baeza *et al.*, 2001) which reported significantly higher body weight in male than female Muscovy from 4 to 15 weeks of age. This is also consistent with Klein-Hessing (2007) who reported significantly higher body weight in Pekin males than females from 6 weeks to 16 weeks of age. The Muscovy had greater sexual dimorphism in body weight between males and females in comparison to the Pekin and this is consistent with several studies that reported similar findings (Bochno *et al.*, 1994; Sauveur, 1990; Wiseman 1987). Pekin females were significantly heavier ($P<0.05$) than their age-matched Muscovy counterparts at all ages from 3 to 16 weeks of age and this is consistent with Swatland (1979) who reported higher body weight in white Pekin than white Muscovy females from day old to 10 weeks of age. Pekin males were significantly heavier ($p<0.05$) than their age-matched Muscovy counterparts from 3 weeks to 6 weeks of age while male Muscovy ducks were significantly heavier than Pekin males from 12 to 16 weeks of age. Early enhanced growth performance (significantly higher body weights from 3 to 6 weeks of age) in Pekin males than Muscovy males found in the current study is consistent with Damaziak *et al.* (2013) who also reported higher body weights in Pekin than Muscovy males from 3 weeks to 6 weeks of age. Significantly higher body weight in Muscovy than Pekin males at 16 weeks of age found in this study is also consistent with Tai and Rouvier (1998).

Generally, Pekin ducks (Combined males and females) had significantly higher body weight (P < 0.05) than their age matched Muscovy counterparts from 3 weeks to 16 weeks of age. Significantly higher body weight in Pekin ducks than Muscovy ducks at all ages from 1 to 16 weeks of age found in the current study is consistent with several studies (Eczny *et al.*, 2015; Bhuiyan *et al.*, 2005). Pekin ducks had significantly higher average daily gain than Muscovy ducks up to 5 weeks of age. Pekin ducks had earlier enhanced average daily gains relative to Muscovy ducks with maximum average daily gain occurring at 5 weeks of age in Pekin and at 7 weeks of age in Muscovy ducks. Early enhanced average daily gains in Pekin than Muscovy ducks is consistent with Wielderhold *et al.* (1997) who also found that Pekin ducks have maximum growth rate earlier than Muscovy ducks.

Higher body weights in Pekin than Muscovy ducks were however also accompanied by significantly higher feed intake in Pekin than Muscovy ducks from 3 weeks to 13 weeks of age. Significantly higher feed intake in Pekin than Muscovy ducks up to 13 weeks of age is consistent with Bhuiyan *et al.* (2005) who also reported significantly higher feed consumption in Pekin than Muscovy ducks at all ages from 1 week to 9 weeks of age. Pekin ducks also had significantly better feed conversion efficiency than their age-matched Muscovy counterparts up to 5 weeks of age and thereafter Muscovy ducks had significantly better fed conversion efficiency than their Pekin counterparts up to 16 weeks of age. Higher feed conversion efficiency in Muscovy than Pekin ducks from 6 to 16 weeks of age found in the current study is consistent with Rashid *et al* (2009) who also found significantly higher feed conversion efficiency in Muscovy than Pekin ducks from 5 to 10 weeks of age. Early enhanced growth performance of both Pekin males and females and their superior feed conversion efficiency up to 5 weeks of age relative to their Muscovy counterparts therefore make them more suitable candidates for selection of meat type ducks. Pekin ducks should however be slaughtered at a much younger age in order to benefit from their superior growth performance and feed conversion efficiency and minimize on feeding costs. Keeping Pekin ducks beyond 12 weeks of age will result in unnecessary feeding costs that do not translate to any weight gains.

In the second study, 8 microsatellite markers were used for the assessment of genetic diversity in the local Muscovy duck population. Observed and effective number of alleles ranged between 5 and 12 and between 2.495 and 5.189, respectively. The mean observed and effective number of alleles in Muscovy were 8.25 and 3.66, respectively and these were comparable with 8.428 and 4.26 found in Chinese native ducks (Li *et al.*, 2006). The observed heterozygosity ranged between 0.435 and 0.913 with mean observed heterozygosity of 0.733± 0.164, while the expected heterozygosity ranged between 0.613 and 0.825 with mean expected heterozygosity of 0.725±0.078. The average observed heterozygosity in Muscovy ducks (0.733±0.164) is comparable to the average observed heterozygosity of 0.693 found in Chinese indigenous laying type ducks using a panel of 17 microsatellite markers (Su and Chen, 2009). The mean expected heterozygosity of 0.725±0.078 in Muscovy ducks is comparable with mean expected heterozygosity of 0.72 and 0.68 found in indigenous Indian ducks and Land and Coastal ducks, respectively (Mukesh *et al.*, 2011; Gaur *et al.*, 2016). The allelic diversity (mean observed and mean expected heterozygosity) all indicated high levels of genetic diversity in the Muscovy duck population of Botswana. All the eight loci studied were also in Hardy-Weinberg equilibrium indicating high genetic stability in Muscovy duck population and confirms lack of any organized selection program in the local duck population. The inbreeding coefficient of the Muscovy population was -0.136 indicating an excess of heterozygotes in the population and therefore negligible levels of inbreeding in the Muscovy duck population. Sufficient genetic diversity therefore exists in the local Muscovy duck population to permit within breed genetic selection in traits of economic importance and to withstand expected climatic changes resulting from global warming.

5.2. CONCLUSIONS

-Pekin ducks had superior growth performance as compared to Muscovy ducks

-Pekin ducks had higher feed consumption as compared to Pekin ducks

-Muscovy ducks had relatively better feed conversion efficiency than Pekin ducks

-High genetic diversity exist within the local Muscovy duck population.

5.3. RECOMMENDATIONS

1. Farmers should use Pekin ducks as meat type ducks than Muscovy due to early enhanced growth performance of Pekin ducks (both males and females) compared to Muscovy ducks.

2. For backyard farming, farmers should rear Muscovy ducks as they require less feed and utilize feed more efficiently as compared to Pekin ducks.

3. The government and Institutions like Universities should lead efforts towards conservation of Muscovy ducks

4. Farmers should exploit the genetic diversity in the Muscovy population through artificial selection to make improvements in traits of economic importance.

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