Evaluation of the Production and Genetic Potential of Indigenous Mukota and their Crosses with Large White Pigs in Zimbabwe

By

Michael Chimonyo

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Department of Paraclinical Veterinary Studies

Faculty of Veterinary Science

University of Zimbabwe

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Approved as to style and content by:

……………………	………………..
Dr K Dzama	**Dr E Bhebhe**
(***Major Supervisor***)	(***Co-supervisor***)

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Abstract

Mukota pig populations in smallholder areas of Zimbabwe are decreasing. The objective of this study was to evaluate the production and genetic potential of the Zimbabwean indigenous pig and Large White × Mukota in commercial pig production. The trial was conducted at the University of Zimbabwe Farm, Harare, Zimbabwe. All dry sows were fed on a high fibre diet. All the fixed effects were analysed using generalised linear models procedure of SAS (2000) and genetic parameters were estimated using average information restricted maximum likelihood. Piglets were weaned at 35 days.

Sows mated to Large White boars had larger litter sizes and total litter weight than Mukota. The growth rate of the two genotypes before weaning was not different ($P>0.05$). Post-weaning growth showed that boars had higher body weight gains than gilts ($P<0.05$). Body weights were consistently higher in the crossbred than in the Mukota pigs ($P<0.05$). Mukota pigs showed a peak growth between 12 and 16 weeks post-weaning. Crossbred pigs had longer ($P<0.05$) carcasses than Mukota (507.2 ± 0.92 versus 655.5 ± 1.68 mm). The genetic correlation between the direct and maternal genetic effects on birth weight was –0.354 and –0.295.

The heritabilities for litter weight at three weeks (LTHRWT), litter weight at weaning (LWWT) and mothering ability (MA) were 0.18, 0.15 and 0.05, respectively. There were no genetic relationships between MA and LTHRWT and LWWT. The heritabilities for growth rates, before and after 12 weeks, were 0.27, 0.21, respectively. There was a positive genetic correlation between weight at weaning and average daily gain from weaning to 12 weeks (r_g = 0.68). The backfat thickness at 50 and 75 mm were highly correlated (r_g = 0.88). Weight at birth was positively correlated with average daily gain from birth to weaning, whereas the relationship of BWT versus weight gain from 12 weeks to slaughter was unfavourable. Selection and crossbreeding can be used to improve smallholder pig production. The presence of the genetic correlations demonstrates the need to use multitrait analyses in evaluating genetic worthiness of pigs.

Dedication

……there being no shortcuts to progress, I dedicate the work to those who preserver with integrity, dedication and wisdom………..…

……numbers of good people are dwindling……fast!

……the future………

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Were it not for the continued support of my wife, Nonkosi, there would have been no thesis to talk of. I sincerely hope that, from now, I will be home early!

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Chapter 1: General Introduction

Pig production in Zimbabwe largely involves the use of exotic breeds; the most common of which are the Large White and the Landrace. The exotic breeds are relatively large in size and so have high maintenance energy requirements, which results in smallholder farmers not affording to participate in commercial pig-meat production. Nearly 60 % of domesticated pigs in Zimbabwe are made up of the Mukota breed (Central Statistical Office, 1997; FAO, 2002). Most of the Mukota breed is confined to communal areas. The Mukota pig is relatively small in size and is able to reproduce at a low plane of nutrition. More importantly for smallholder farmers, this breed has the ability to utilise diets containing high levels of fibre, which are cheaper (Kanengoni *et al*., 2002; 2004; Ndindana *et al*., 2002).

The intensive selection and genetic improvement in the exotic breeds have resulted in high growth rates and bigger carcasses. The improved breeds are, however, not well adapted to the tropical environments, which are generally hot. Indigenous breeds could also be less susceptible, resistant or tolerant to some specific diseases and parasites. Zanga *et al*. (2003), for example, showed that the Mukota pigs are less susceptible to *Ascaris suum*, the most important internal parasite of pigs. The rapid increase in human population also means that animals have to be sustained on small pieces of land, with scarce food resources. Indigenous breeds could, therefore, be of much significance under such marginal production conditions.

According to FAO (2002), many trials that compare indigenous and exotic breeds are biased towards the latter. In addition, most trials are brief and poorly designed, with substantial feeding and management biases favouring the exotics. Comparative research is often done in environments where feed, water, disease control and management inputs are very different to those in the real farming community. Although it is generally difficult to conduct breeding trials on-farm, particularly due to the need for controlled breeding of the trial animals, there is need to generate production and genetic parameters under conditions that mimic smallholder production conditions.

It is imperative that any pig improvement programme should incorporate the adapted indigenous breeds, or genes from them. This would increase the sustainability of the project and result in potential large future benefits. The extent to which indigenous breeds can be improved through selection is not known. This is largely because both the genetic and non-genetic factors that influence the performance of these breeds have not been established. Traits of economic importance include reproductive, growth, mortality, carcass and meat quality. Reproductive traits of importance are litter size, weight of pigs at birth and number of piglets born alive or dead. Feed intake, growth rate and feed conversion efficiency are the important growth performance traits that should be considered in selection programmes. Meat quality is another trait of economic importance as it directly influences the demand of the pig meat. Non-genetic or environmental factors that influence productivity include season of farrowing and weaning, parity or age of sow, sex of the pig, nutrition and the level of management. The adaptability of indigenous breeds could complement the large sizes of the exotic breeds (Adebambo, 1986;

Chimonyo *et al*., 2001). The crossbred could, possibly, be the ideal animal to use if smallholder farmers are to venture into commercial pig production.

1.1 Justification

With the recurrent droughts accompanied by an increase in human maize consumption in third world countries, existing pig production systems have become unsustainable, particularly for resource-poor smallholder farmers. Recent evidence (Kanengoni *et al*., 2002; Ndindana *et al*., 2002) indicates that indigenous pigs and crossbreeds between the indigenous and exotic pigs could be sustained on low quality fibrous diets. Examples are agricultural by-products and/or crop residues, which are not utilised by humans as food. Most agricultural by-products are usually wasted or burnt for fuel. The use of crop residues will increase productivity of farming systems and, therefore, boost smallholder agricultural output.

The practice of indiscriminate crossing of indigenous with exotic pigs in smallholder farming poses a threat to the very survival of indigenous Mukota pigs as a breed. Establishment of the performance levels of Large White × Mukota crossbreds would assist farmers and policy-makers in designing crossbreeding programmes that maximise returns to the smallholder farmers. The Large White × Mukota is the most common type of crossbred pig in smallholder areas since Large White boars are the preferred sire line in commercial pig production systems. Smallholder farmers then mate the boars with indigenous Mukota dam lines. There is need to generate genetic parameters, such as heritability and genetic correlations among traits, particularly for the Mukota pigs. The heritability estimates determines the breeding values of the individual animals and genetic correlations are particularly useful in indirect selection of traits. Genetic parameters are useful to design selection and genetic improvement programmes for the Mukota pigs, which assists in developing conservation programmes, largely through utilisation. Important genetic parameters are heritability and genetic correlations. Heritability of a trait is used to compute the breeding values of individual animals in a herd. Correlations are essential selecting for traits that are genetically related to each other, such that selecting for one result in an indirect selection for the other.

1.2 Objectives

The main objective of this study is to evaluate the production and genetic potential of the Zimbabwean indigenous (Mukota) pig and Large White × Mukota in commercial pig production. The specific objectives are to:

1. Determine the environmental factors that influence the reproductive performance of indigenous Mukota pigs and its crosses with the Large White (LW) pigs;
2. Assess the environmental factors that influence growth and determine growth patterns of the Mukota and Large White × Mukota pigs when fed on a diet containing high levels of fibre;
3. Evaluate the environmental factors that affect the carcass characteristics of the breed lines; and
4. Generate genetic parameters (heritability and genetic correlations) for reproductive, growth and carcass traits in indigenous pigs;

Chapter 2: Review of Literature

2.1 Introduction

There is little information on the production and genetic potential of Mukota pigs. This review of literature discusses the attributes of Mukota pigs and methods of improving smallholder pig production are also evaluated. The other sections deal with genetic evaluation of pigs, choice of appropriate statistical models and the major genetic parameters that are considered in increasing the accuracy of selection of pigs. Traits of economic importance in pigs and the genetic parameters available in literature are also reviewed.

2.2 Smallholder pig production in Zimbabwe

The increasing demand for meat due to population growth and the limited potential to increase the meat offtake from ruminants in the smallholder areas lead to the question of the potential of smallholder pig production and its possible contribution to the meat market. Pig productivity in smallholder areas of Zimbabwe is generally low. Smallholder pig producers use the free ranging system during the dry season and the pigs are housed in simple houses during the rainy season (Holness, 1991). Moreover, they survive under unhygienic conditions. During confinement, they are given feeds such as maize, coarse maize meal, maize husks, green maize, kitchen waste, cabbage waste, pumpkins, groundnut shells, fruits, grasses and brewers waste (Scherf, 1990).

Improvement of smallholder pig production should, ideally, be based on the indigenous breeds, since they have been bred and kept under the extensive production systems for a long time. There is also potential to use the Mukota pigs in commercial production and in crossbreeding. They have been demonstrated to efficiently utilise agricultural by-products, such as maize cobs (Ndindana *et al*., 2002; Kanengoni *et al*., 2004). Utilisation of agricultural by products, which normally wasted or burnt away, increases the returns and sustainability of agricultural production systems for smallholder resource-poor farmers. As a result, food security, especially consumption of animal based proteins, will increase. There is, however, need to evaluate other fibrous diet, such as those containing maize bran, wheat bran and brewer's grain.

In communal areas, pigs are sold to solve financial constraints usually encountered in the rural areas, such as payment of school fees and sending household members to hospitals. Sustainable pig production should, thus, be based on the indigenous breeds. Exotic breeds have a high requirement for resources and inputs, since they have been bred under relatively benign environmental conditions, which are quite different to the conditions experienced in rural areas. The purposes of pigs for rural people can be put into four categories namely: socio-economic functions, production of goods (Ndiweni and Dzama, 1995), cultural and ceremonial roles and provision of services (Epstein, 1983; Mashatise, 2002).

2.3 Attributes of Mukota pigs

A considerable number of positive attributes have been demonstrated in Mukota pigs. Most of the attributes relate to their hardiness and adaptation to survive under smallholder farming environments.

2.3.1 Small body size and low nutrient requirements

Mukota pigs are small in size, with mature weights of about 100 kg. They have low maintenance and growth nutrient requirements. For example, Chulu *et al*. (2002) indicated that Mukota pigs have less dietary protein requirements than Large White pigs. More work is, however, required to determine their optimum protein requirements and metabolism. The requirement for lower amounts of nutrients is of importance in rural areas, where resources are limiting. Coupled with the slow growth rates, Mukota pigs are early maturing. They tend to deposit body fat earlier than fast-growing exotic pigs. The growth curves and development patterns of the Mukota pigs, however, need to be determined to estimate the appropriate ages and body weights at slaughter.

2.3.2 Utilisation of agricultural by-products and fibrous diets

It has been reported that local pigs have enhanced abilities to utilise fibrous feeds compared with imported genotypes, such as the Large White breed (Kanengoni *et al*., 2002). In smallholder areas, feed resources are scarce and, if available, prices can be prohibitive. The use of alternative agricultural by-products, such as maize cobs (Ndindana *et al*., 2002), which are usually thrown away, increases the interdependence of farm enterprises, as products from crop production are channelled towards pig production whilst manure will be used to fertilise crops. Utilisation of agricultural by-products and crop residues increase the options and number of feed ingredients or feedstuffs that can be used in pig production. Use of local and readily available feed resources can promote the sustainability of smallholder pig production (Ly *et al*., 1998) and increase the efficiency of resource utilisation (Ly, 2000). The ability of Mukota pigs to utilise agricultural by-products means that there will be less demand for cereals, thereby decreasing competition with humans. The capacity for fibre utilisation could, probably, be related to the relatively large size of the colon and caecum (Dzikiti and Marowa, 1997).

2.3.3 Utilisation of tannin-rich diets

Mukota pigs are traditionally fed on feeds such as forages, pumpkins and kitchen wastes (Mashatise, 2002). White sorghum has been used in feeding pigs as a substitute for maize. Red sorghums are not used because of their high content of tannins. It has, however, been established that Mukota pigs are better able to utilise red sorghum than Large White pigs (Mushandu, 2000). The mechanism is not clear, although it could be linked to the production on proline-rich proteins (Mehansho *et al*., 1987) in the saliva or the superior hindgut fermentation. Hindgut fermentation is likely to increase the digestibility of the fibre and increase the utilisation of volatile fatty acids from the caecum and colon. Utilisation of high tannin sorghum varieties could boost smallholder pig productivity, since most smallholder farmers grow red sorghums, as they resist attack by birds. Red sorghum is also grown in dry and marginal areas, which are unsuitable for maize production.

2.3.4 Tolerance and resistance to parasites and diseases

Mukota pigs, which are traditionally raised under extensive management systems with minimal health care (Mashatise, 2002), are regarded to be hardy and resistant to most parasites and diseases. Zanga and co-workers (2003) reported that Mukota pigs are less susceptible to *Ascaris suum*. These authors demonstrated Mukota pigs to be less susceptible to *A. suum* infection than Large White pigs. In the same experiment, the reduction in body weight gains was also low in Mukota pigs as compared to Large White growing pigs (Zanga *et al*., 2003). *Ascaris suum* is one of the major factors that reduce productivity in pigs. It is not clear whether the tolerance is genetically influenced.

2.4 Methods for the improvement of smallholder pig production

2.4.1 Community-based management of animal genetic resources

Community-based management of animal genetic resources describes the management of animal genetic resources (AnGR) in which decisions of defining, prioritising and implementing actions that affect the AnGR and agro-ecosystems are made by the local communities who own these resources. Management of AnGR should involve participation by the communities, for which the results are directed and who, also keep these resources. Participation increases service coverage, improves operations and maintenance, stimulates broader socio-economic development and enhances the community's capacity for problem solving. It also brings about ownership of the activities and products and, consequently, the likelihood of success and sustainability. Community ownership also exploits the wealth of indigenous knowledge of the local peoples. Indigenous knowledge assists, for example, in understanding the breeding practices and selection criteria used by the local people. The programmes, thus, have the potential to increase Mukota pig population sizes. Increased numbers increase selection intensities and, thereby, genetic progress.

2.4.2 Crossbreeding

Crossbreeding is the mating of individuals from different breeds to exploit genetic variation. Use of different breeds is utilised to enhance productivity through the exploitation of heterosis and breed differences (Pathiraja, 1986), breed additive effects and breed maternal effects. Crossbreeding is also carried out to take advantage of breed complementation, developing new breeds and introducing new genes into the population (Solkner, 1993). The performance of different crossbreds under smallholder production conditions should be evaluated to maximise the genetic gains of heterosis and breed complementarity. In smallholder areas, there is indiscriminate crossbreeding, which threatens the survival of the Mukota pigs. There is need to generate genetic parameters for the Mukota pigs and to evaluate performance of reciprocal crosses to determine the optimum genotype for smallholder pig production.

2.5 Genetic evaluation

2.5.1 Mixed model equations

To achieve genetic improvement, genetic evaluation of animals is mandatory. There is need to identify traits of economic importance and accurate recording of the data. All evaluations require the estimation of variance and covariance components. These components are usually estimated using a mixed model, a model that includes both fixed and random sources of variation to explain the variation in the dependent variable, for example growth rate of pigs. The general mixed model is written, in matrix notation as:

$\mathbf{Y} = \mathbf{Xb} + \mathbf{Zu} + \mathbf{e}$; where;

Y is an N × 1 vector of observations

b is a p × 1 vector of unknown constants

u is a q × 1 vector of unknown effects of the random variables

e is an N × 1 vector of unknown residual effects, and

X, Z are known matrices of order N × p and N × q, respectively, that relate elements of b and **u** to elements of **Y**.

The elements of **b** are considered to be fixed effects while the elements of **u** are the random effects with known variance-covariance structure. Both **b** and **u** may be partitioned into one or more factors depending on the situation. For example, a model can contain two random effects, such as direct animal genetic effect and maternal genetic effect. In pig data, a third component of **u**, the common environmental litter effect, is also usually fitted (Keele *et al*., 1991).

The expectations of the random variables are:

$E(\mathbf{u}) = 0$

$E(\mathbf{e}) = 0$

$E(\mathbf{Y}) = E(\mathbf{Xb} + \mathbf{Zu} + \mathbf{e})$

$= E(\mathbf{Xb}) + E(\mathbf{Zu}) + E(\mathbf{e})$

$= \mathbf{X}E(\mathbf{b}) + \mathbf{Z}E(\mathbf{u}) + E(\mathbf{e})$

$= \mathbf{Xb} + \mathbf{Z}(0) + 0$

$= \mathbf{Xb}$

For mixed models, the variance-covariance structure is typically represented as:

$$V\begin{bmatrix} u \\ e \end{bmatrix} = \begin{bmatrix} G & 0 \\ 0 & R \end{bmatrix},$$

where **G** and **R** are known, positive definite matrices. Consequently,

$$\mathrm{V} = \mathrm{V}(\mathbf{Xb} + \mathbf{Zu} + \mathbf{e})$$

$$= \mathrm{V}(\mathbf{Zu} + \mathbf{e})$$

$$= \mathbf{Z}\mathrm{V}(\mathbf{u})\mathbf{Z}' + \mathrm{V}(\mathbf{e}) + \mathbf{Z}\mathrm{Cov}(\mathbf{u}, \mathbf{e}) + \mathrm{Cov}(\mathbf{e}, \mathbf{u})\mathbf{Z}'$$

$$= \mathbf{ZGZ}' + \mathbf{R}$$

$$\mathrm{Cov}(\mathbf{Y}, \mathbf{u}) = \mathbf{ZG}$$

$$\mathrm{Cov}(\mathbf{Y}, \mathbf{e}) = \mathbf{R}.$$

2.5.2 Methods of variance-covariance estimation

Estimates of the variance-covariance components are needed to compute heritability and genetic correlations between traits. There are several methods that are used in estimating variance components. These include analysis of variance, maximum likelihood, minimum norm quadratic unbiased estimation, symmetric differences squared, pseudo expectation approach and the tilde-hat approach. Heritability estimates can also be estimated directly as twice the regression of offspring on parent (Falconer and Mackay, 1996).

One of the recommended methods for estimating variances and covariances is the restricted maximum likelihood (REML). In essence, the REML method deals with linear combinations of the observed values whose expectations are zero. These 'error contrasts' are free of any fixed effects in the model. In contrast to other methods, REML estimates are unbiased and more precise, especially when applied on the animal model. The animal model is used when both the sire and dam of an individual are used to estimate the variance components.

The REML estimates in balanced designs are identical to Analysis of Variance estimates. With ANOVA estimates, one equates estimated mean squares to their expectations and solves for the variance components in those expectations. The ANOVA method is quite simple and is not computationally intensive. However, designs often lack balance because of missing experimental units, the frequent need for use of a covariate, and/or non-homogeneous variances, making REML estimates more appropriate than ANOVA.

Choice of the algorithm to use depends on availability, capacity of the computer and size of the data set. The methods that currently used are largely REML-based. Various modifications and improvements have been made and REML is now available in various versions. Common types of REML are derivative free REML (DFREML) (Meyer, 1993), average information REML (AIREML) (Gilmour *et al*., 1995), multi-trait derivative free REML (MTDFREML) (Boldman *et al*., 1993) and ASREML.

2.5.3 Choice of statistical models to estimate variance components

Accurate estimates of genetic parameters are essential in estimating breeding values and optimising prediction of genetic response to selection. Traits such as growth rate are not only influenced by the genotype of the animal, but also by the maternal environment. For example, maternal effects are important to animal breeders who would like to eliminate the influence of the effects so that selection is for direct genetic merit. Suitable models, however, for estimating variance components are generally unknown.

The importance of maternal genetic effects in estimating variance-covariance components is still controversial. Using REML under the animal model, Perez-Enciso and Gianola (1992) found no maternal effects and Roehe (1999) and Kaufmann *et al*. (2000) reported significant presence of maternal effects. These contradictions suggest that the presence of maternal effects depends on the traits, population structure or models for estimating maternal effect (Satoh *et al*., 2002).

Several studies have compared different animal models with respect to direct and maternal genetic variance-covariance and common litter variance components for reproductive traits in swine (Roehe and Kennedy, 1995; Alfonso *et al*., 1997; Hermesch *et al*., 2000). Their results suggested that the parameter estimates are specific to models used. However, as the true model for estimating variance components is generally unknown, the choice of the suitable statistical model is of paramount importance. The use of a simpler model may be appropriate only in the absence of maternal and common litter effects. Simpler models also result in biased estimation of the direct genetic effect and, thereby, the direct heritability (Haley and Lee, 1992; Satoh *et al*., 2002). This applies, especially, for birth weight, litter weight, three-week weight and weaning weight. Maternal genetic effects are also overestimated when maternal environmental effects are ignored (Alfonso *et al*., 1997). Changes of correlation between additive direct and maternal genetic effects also affect the estimates of variance components when models used are inappropriate (Meyer and Hill, 1992). Satoh *et al*. (2002) concluded that the most accurate estimates are generated when all random effects (direct, maternal and litter effects) are incorporated. The magnitude of these components in Mukota pigs is required to design an effective pig improvement programme.

2.5.4 Genetic parameters

Important genetic parameters that are necessary in genetic improvement of livestock are heritability and genetic correlations.

2.5.4.1 Heritability

For accurate selection, there is need to estimate genetic parameters, such as heritability and genetic correlations. Such parameters have not been estimated for Mukota pigs. Heritability expresses the strength with which a quantitative trait is inherited (Falconer and Mackay, 1996; Wiener, 1994). Heritability estimates in pigs differ with type of traits. Falconer and Mackay (1996) reported heritabilities of 5, 40, 50 and 70% for litter size, daily gain, feed conversion efficiency and backfat thickness. These values show that the benefits from the inclusion of litter size in selection programmes are quite small. Heritability is affected by the environmental conditions to which the individuals are subjected.

2.5.4.2 Genetic correlations

Genetic correlations are largely caused by pleiotrophy, a condition whereby a single gene affects two or more traits. For example, genes that affect growth rate increase both stature and weight. This means that selection for increased growth and reduced backfat leads to a corresponding improvement in the feed conversion efficiency and mature body size (Lo *et al*., 1992). The extent of such relationships in Mukota pigs is not known and needs to be quantified.

2.5.4.3 Maternal genetic effects

In livestock, the female provides for its offspring to survive and grow. Females vary in their ability to provide a good environment for their offspring, and this variability is likely to have a genetic basis (Satoh *et al*., 2002). Maternal ability is transmitted from both parents, but is only expressed by females when they produce litter. Models have been developed to account for the maternal genetic effects in pigs. In some cases, a relationship exists between the direct and maternal effects (Roehe, 1999). If the correlation between the direct and maternal true breeding values is negative, and if an animal has a high direct breeding value based on its own growth record, then the maternal breeding value could be very negative due to the correlation alone. If many of the animals in the data set with records have progeny too, the correlation between direct and maternal is more accurate and closely follows the assumed genetic correlation.

2.5.4.4 Common environmental litter effects

Common environmental litter variation represents the effects specific to a particular litter. These include the non-genetic components of uterine nutrition and the capacity of the uterus to carry all the foetuses to term. Litter effects also include the non-additive genetic effects, such as dominance. Litter effect estimates in literature ranges from 0.08

(Hermesch *et al*., 2000) to as high as 0.24 (Roehe, 1999) for birth weight, probably indicating the large variation in birth weight within litters.

2.6 Non-genetic factors affecting smallholder pig production

For an animal to express its full genetic potential, the environmental conditions should be conducive. All factors that are not determined genetically are called environmental factors or non-genetic factors. Non-genetic effects are likely to be different between commercial intensive and smallholder production systems. The major non-genetic factors that influence pig productivity are the month and season of birth, breed of the sire, dam and the progeny, age or parity of the dam, sex of the pig, type of mating and the level of management.

2.6.1 Parity of sow

The parity of the sow has been reported to influence several traits in pigs. It has been reported to influence litter size, litter weights and performance at weaning (Adebambo, 1986). Mungate *et al*. (1999) also obtained significant parity effects on litter size at birth, average birth weight, average weight at three weeks and average weight at weaning. Differences between litter sizes are usually significant between the first and second parities. Differences among the latter parities are small. As such, it is recommended that when computing genetic parameters, the first and the subsequent parities should be treated as different traits (Perez-Enciso and Gianola, 1992; Roehe and Kennedy, 1995). The differences are largely related to age of the sow, the uterine capacity and milk production by the sow.

2.6.2 Month and season of farrowing

Seasonal effects on sow productivity are well documented. Under intensive production systems, differences in performance across different seasons relate to changes in ambient temperature, rainfall and humidity. Pregnant or lactating sows eat less during the hot months and lose more weight. In addition, boars are less fertile during hot months. Variations in sow performance call for farmers to adjust their breeding programmes accordingly. Mungate *et al*. (1999), in Zimbabwe, reported seasonal effects on litter size and weights at three weeks and at weaning. In smallholder production environments, housing conditions are poor, such that the highest causes of piglet mortality are the draughts (Mashatise, 2002). Season also influences the availability of feed resources in communal areas. For example, pigs receive high energy diets, such as pumpkins, during the rainy season, and survive on agricultural by-products during the dry season.

2.6.3 Breed

Breed of pig has been established to influence the performance of pig herds. The Large White is known to have higher growth rate and superior feed conversion efficiency. The Landrace produces long carcasses and is superior for its high litter sizes at birth. The carcass and meat quality of Duroc has been rated as excellent (Chen *et al*., 2002). Mukota pigs have also been established to be superior to the Large White pigs with respect to utilising fibrous diets (Kanengoni *et al*., 2002, 2004; Ndindana *et al*., 2002) and tolerance to parasites (Zanga *et al*., 2003). Choice of breed should, thus depend on the personal perceptions of the producer, the characteristics of the consumers and, more importantly, the production system (Kanengoni *et al*., 2002).

2.6.4 Other factors

Other non-genetic factors that influence pig productivity and the magnitude of selection response include sex of the pig, type of mating and the level of management. Males tend to grow faster than females, especially so after puberty, due to the effect of males hormones. Artificial insemination has not been as successful in pigs as in other species. This is largely due to the difficulty of handling boar semen. As such, herds that use artificial insemination tend to have smaller litter size averages than those that employ natural service. The use of improved technologies, such as artificial insemination depends on the inputs and level of management of the producer. Level of management encompasses aspects such as the level and frequency of feeding, the quality of the feed ingredients used, the disease prevention and control measures and the quality of the stockmen.

2.7 Traits of economic importance in pig breeding programmes

Reproductive, growth, carcass and meat quality characteristics are the main traits that are focussed on in pig improvement programmes. Traits of economic importance are likely to differ across production environments and market demands. For example, piglet viability is likely to be more important in smallholder pig production systems than litter size.

2.7.1 Reproductive traits

Reproductive traits generally reflect the performance of the sow. These include the number of pigs born per litter, the number of pigs born alive, number of pigs born dead and weight of the litter at birth. Litter size, however, starts with ovulation rate and the capacity of the boar to fertilise the sow. Average birth weight and individual birth weight of the pigs are also traits of economic importance. Although there are numerous articles on litter performance, the genetic determination of individual weight at birth is still scarce. Most traits have low heritability (below 10 %). Reproductive performance, which is usually a trait of the dam, also includes the ability of a sow to nurse pigs up to weaning. Thus, the other traits of importance include the growth rate of the pigs up to weaning (Mungate *et al*., 1999), litter size at weaning, mothering ability of the sow and the ability to conceive soon after weaning. The maternal genetic effects are also high in reproductive traits, and their contribution tends to decline as the pigs grow (Kaufmann *et al*., 2000).

2.7.2 Growth performance traits

Productive performance refers to the efficiency of meat production, which is a function of growth rate, feed efficiency and carcass quality (Kuhlers *et al*., 2003). The measurement of efficiency in pigs can be based on body weight gain and feed conversion efficiency and lean growth rate (Chen *et al*., 2002).

2.7.3 Carcass traits

Carcass traits include backfat thickness, either determined in a live pig (using ultrasound) or at slaughter. Carcass measurements also include drip loss, fat and eye muscle depth, weight of the hind legs, lean weight of the legs. Intramuscular fat content is also important, as it influences the taste of the meat (Newcom *et al*., 2002). The heritabilities of these traits have been found to be moderate and high (Hermesch *et al*., 2000).

Fernandez *et al*. (2003) reported a heritability of 0.25 for fat content within the *longissimus* muscle in Iberian pigs.

2.7.4 Meat quality traits

While body weight is one of the simplest parameters to measure, it can be an inaccurate measure of the targets for the animal breeder. Because consumer demand is for lean meat with minimum fat content, the rates of gain of edible meat and of lean tissue would seem to be the targets in breeding experiments. Unfortunately, such parameters are difficult and expensive to measure. In addition, handling and eating quality characteristics of pig-meat are becoming increasingly important to meat processors and consumers as ready-made meat products and the incidence of eating outside the home increase (National Research Council, 1988; Lo *et al.,* 1992a). Consumers eat more meals away from home and consume more pre-cooked products and oven-ready products.

Meat quality traits have low to medium heritability (Hermesch *et al*., 2000). Examples of meat quality traits include pH immediately after slaughter, pH after 24 hours of slaughter, and colour of the *longissimus dorsi* muscle.

2.8 Conclusions

Mukota pigs have several attributes, although their genetic determination is not yet characterised. There is need to determine the production and genetic factors that influence Mukota pigs, especially under environmental conditions that mimic smallholder production conditions. The objective of this study was, therefore, to evaluate the production and genetic potential of Mukota pigs in Zimbabwe when fed on fibrous diets.

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Chapter 3: Non-Genetic Effects of Number of services per Conception, Gestation Length, Farrowing Interval, Litter Size and Birth Weight

Abstract

The objective of this study was to determine non-genetic effects of sow and litter productivity at birth in Mukota sows mated to Mukota and Large White boars. The trial was conducted at the University of Zimbabwe Farm, Harare, Zimbabwe. All matings were through natural service. Dry sows were fed on a high fibre diet. The mean number of matings per conception was 1.3 and decreased ($P<0.05$) with an increase in parity. Gestation length ranged from 99 to 127 days, with an average of 114.3 days. The mean farrowing interval was 156 days. Farrowing indices were high during the first three parities and were low in later parities. The total and average weights of pigs at birth were low in the first two parities and increased from parity 3. The total number of pigs born (NBT) and number of live pigs at birth (NBA) were lower in sows sired by Mukota boars than those sired by Large White boars. The average NBT and NBA were 8.0 and 7.1, respectively. The highest litter sizes were obtained in parities 6 and 7. Crossbred pigs were heavier than purebred Mukota litters at birth. The average birth weight of piglets from sows mated to Mukota and Large White boars were 0.70 and 0.99 kg, respectively.

3.1 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). These pigs are adapted to the local, usually harsh, environments in which they have been kept for centuries. They are largely kept in the rural areas, where resources are scarce and poor. They scavenge for food. The local pigs from Zimbabwe, generally known as Mukota, have been established to be better able to utilise agricultural by-products, such as maize cobs than imported pigs (Chimonyo *et al*., 2001; Kanengoni *et al*., 2002; Ndindana *et al.,* 2002). They have also been reported to reproduce under low planes of nutrition (Holness, 1972) and are tolerant or resistant to parasites (Zanga *et al*., 2003). Utilising indigenous pig genetic resources that are adapted to the local environmental conditions can enhance sustainability of smallholder pig production systems, at the same time promoting the utilization of their valuable genes (Scherf, 1990; Anderson, 2003). It has been shown that the feed needed by one pig of an imported breed to produce a litter of 10 piglets is sufficient for two and a half indigenous sows and a combined litter of 20 piglets (Holness, 1991). The lack of sufficient characterization of the local genotypes, however, makes it difficult to use them in pig improvement schemes. There is no information on the farrowing intervals, gestation lengths and other measures of reproductive performance in Mukota pigs.

Reproductive performance of the sow is of major economic importance to pig producers, as it is the first determinant of the number of saleable pigs on the farm. Improvement of litter size or sow productivity, however, is difficult since the actual causes of variation are not easily quantifiable (Adebambo, 1986). Most traits that are related to fitness or reproductivity have low heritabilities, suggesting that slow gains are achieved through selection. The pig producer, should, therefore, be cognizant of the major sources of variation and their relative importance in affecting measures of sow productivity. Some important non-genetic factors of sow productivity in imported breeds include parity of the sow, month of mating and farrowing, farrowing intervals, year of farrowing and general management, which includes nutrition and health (Mungate *et al*., 1999). The contribution of such factors in local pigs is not known, yet extensive indiscriminate crossbreeding between imported breeds and the local pigs is widespread (Scherf, 1990). The objectives of this study were, therefore, to determine non-genetic effects of sow and litter productivity at birth in Mukota sows mated to either Mukota or Large White boars, when fed fibrous diets.

3.2 Materials and Methods

3.2.1 Study site

The trial was conducted at the University of Zimbabwe Farm (UZF), Harare, Zimbabwe. The altitude is approximately 1300 metres above sea level. The area is situated at 18ºN and 30ºE. Annual rainfall averages 800 mm.

3.2.2 Animals and pig selection

Unrelated Mukota boars and 16 Mukota gilts were bought from three different geographic areas. The first batch was obtained from Mutoko Communal Area, nearly 250 km to the north east of Harare, Zimbabwe. The pigs were bought to develop a satellite population on-station at the University of Zimbabwe Farm. The other local pigs were obtained from Mvuma, which lies about 300 km to the south of Harare. This was meant to increase diversity, broaden the genetic base in the herd and reduce inbreeding. The third set of pigs was obtained from Mount Darwin, about 200 km to the north of Harare.

Eleven gilts were obtained from Mutoko, two from Mvuma and three were obtained from Mount Darwin. Three Mukota boars were obtained from Mutoko. Gene frequencies among the three populations were assumed to be the same. Four purebred performance-tested Large White boars were obtained from the Pig Industry Board Farm (PIB), Arcturus, Zimbabwe. It has the mandate for developing pig improvement strategies in Zimbabwe. The Large White boars were used for crossbreeding with Mukota sows.

Mating was done in a way that avoided or reduced inbreeding, based on pedigree records. The boar: sow mating ratio was 1: 6. Animals with a relationship coefficient of above five percent were not mated to each other. All matings were through natural service. Sows were culled after the eighth parity. Gilt replacements were selected on a within-litter basis. No more than one gilt was selected from the same litter. The gilts selected for breeding had above average daily gains and having at least 12 teats. Gilts with vulvas that were not up-turned and with strong legs were selected. Gilts produced from litters that had a tendency to savage its offspring were not considered to be part of the breeding herd. Litter size was not used as a basis for selection. Selection of boars was based on body confirmation, shape and pedigree, to avoid or reduce inbreeding. All the pigs that were not selected for breeding were put on the commercial unit and were destined for slaughter.

3.2.3 Pig management

The management and feeding conditions of the pigs were designed to mimic the conditions that are experienced in smallholder farming areas. Sow houses had no creep areas, farrowing crates and infrared lamps. All dry sows were fed on a high fibre diet. The ingredient composition of the diet is presented in Table 3.1. Boars were maintained on 2 kg a day of the same diet as for sows. Lactating sows were fed on 2 kg of commercial brood sow meal a day with an additional allowance of 0.5 kg for each piglet. Piglets were weaned at five weeks of age. No creep feeding was practised and the piglets depended largely on their mother's milk for growth. Feeding was done at 0630 and 1500 h. Drinking water was supplied to all the animals through low-pressure nipple drinkers (about 1 bar), at all times.

Boars and sows were housed separately, in multi-purpose pens. Breed groups were penned separately. The boars were penned singly while sows were kept three in a pen. All the pens had concrete floors and the size of each pen was about 9 m^2. The pens had roofs that extended the whole pen length and were well ventilated. All pens were cleaned daily. The walls were disinfected against mange mites every two weeks.

Sows and gilts were checked for signs of oestrus daily. Homosexual behaviour, swollen vulva and the standing reflex were the major signs used in heat detection. Mature boars were allowed to stroll along the sow pens as an aid to heat detection and to stimulate ovulation. When a sow was detected to be on standing heat, it was removed from its pen and put in the boar's pen for mating. All matings were natural. Sows were mated three times using the same boar at 12-hour intervals after standing heat to ensure successful mating. Heat detection was repeated 21 days later on the mated sows, and sows that did not show signs of heat were presumed pregnant. Mating was occasionally aided.

Table 3.1: Ingredient and chemical composition of the diet for dry sows and boars

Ingredient composition	**g/kg**
Maize	559.5
Soyabean meal	160.0
Maize cobs	250.0
Mineral/vitamin pre-mix[1]	3.5
Monocalcium phosphate	12.0
Limestone	15.0
Chemical composition	
Crude protein	162.0
Neutral detergent fibre	410.0
Metabolisable energy (MJ ME/kg)	9.6

[1] The premix was obtained from National Foods, Pvt, Ltd, Harare, Zimbabwe.

Seven days before the expected date of farrowing, each sow was put in its own pen and monitored closely. Grass bedding was provided in each pen. Immediately after farrowing, the umbilical cord of each pig was cut and iodine applied. All pigs born alive were ear-notched for identification.

3.2.4 Traits analysed

Data from 434 litters farrowed between January 1998 and August 2003 were captured to evaluate sow productivity at birth. There were a total of 434 litters, 350 of which were the pure Mukota pigs while 84 were litters of Mukota sows mated with Large White boars. The data that were captured included the date of mating, boar identity, number of services per conception, date of farrowing, farrowing intervals, sex of the pig, number of pigs born in total (NBT), number of pigs born alive (NBA), number of pigs born dead (NBD) and litter weight. Weights were determined within 12 hours of birth.

Traits studied were number of services per conception (NOMTG), gestation length (GLNTH), farrowing interval (FI), farrowing index (FX), NBT, NBA, NBD, total litter weight at birth (TBWT) and individual pig weight at birth (IBWT). The FX was computed as:

$$FX = \frac{365}{FI}.$$

3.2.5 Statistical analysis

All traits were analysed using the Generalised Linear Models (GLM) procedure of the Statistical Analysis System (SAS, 2000), assuming fixed models with all possible first-order interactions.

Models for final analysis were obtained after eliminating interactions that were not statistically important (P>0.05). The fixed factors considered were the breed of sire, season of mating, season and year of farrowing, parity of sow, sex of piglet and the relevant covariates. Before analyses, the variables NOMTG, NBT, NBA and NBD were transformed using the square root transformation to normalise them. The least square means and their respective standard errors were back transformed in the presentation of results. The final models for NOMTG (Model 1), GLNTH (Model 2), FI (Model 3), FX (Model 4), TBWT (Model 5), AVBWT (Model 6), IBWT (Model 7), NBT (Model 8), NBA (Model 9) and NBD (Model 10) were as follows:

Model 1: Number of matings

$Y_{ijkln} = \mu + G_i + P_j + M_l + L_m + (G \times P)_{ij} + (G \times M)_{il} + E_{ijklmn}$;

Model 2: Gestation length

$Y_{ijklmn} = \mu + G_i + P_j + M_l + L_m + (G \times P)_{ij} + (G \times M)_{il} + \beta_1 TBWT + \beta_2 NBT + E_{ijklmn}$;

Model 3: Farrowing interval

$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + (G \times P)_{ij} + \beta_3 GLNTH + E_{ijklmn}$;

Model 4: Farrowing index

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + (G \times P)_{ij} + \beta_3 GLNTH + E_{ijklmn};$$

Model 5: Total birth weight

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + \beta_4 NBA + E_{ijklmn};$$

Model 6: Average birth weight

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + \beta_4 NBA + E_{ijklmn};$$

Model 7: Individual birth weight

$$Y_{ijklmno} = \mu + G_i + P_j + S_k + L_m + R_n + (G \times S)_{ik} + \beta_4 NBA + E_{ijklmno};$$

Model 8: Total number of piglets born

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + \beta_5 TBWT + E_{ijklmn};$$

Model 9: Number of piglets born alive

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + \beta_5 TBWT + E_{ijklmn};$$

Model 10: Number of piglets born dead

$$Y_{ijklmn} = \mu + G_i + P_j + S_k + L_m + (G \times S)_{ik} + \beta_5 TBWT + E_{ijklmn};$$

where:

$Y_{ijklmn(o)}$ = an observation

μ = overall mean response

G_i = fixed effect of the i^{th} genotype of sire

P_j = fixed effect of the j^{th} parity of dam

S_k = fixed effect of the k^{th} month of farrowing

M_l = fixed effect of the l^{th} month of mating

L_m = fixed effect of the m^{th} year of farrowing

R_n = fixed effect of sex of piglet

$(G \times S)_{ik}$ = genotype × season of farrowing interaction

$(G \times P)_{ij}$ = genotype × parity interaction

β_1 = partial linear regression coefficient of the dependent variable on TBWT

β_2 = partial linear regression coefficient of the dependent variable on NBT

β_3 = partial linear regression coefficient of the dependent variable on FI

β_4 = partial linear regression coefficient of the dependent variable on NBA

β_5 = partial linear regression coefficient of the dependent variable on TBWT

$E_{ijklmno}$ = residual error distributed as N $(0, I\sigma_e^2)$.

Correlation analyses among NBA, TBWT, AVBWT and GLNTH were performed using the PROC CORR procedure (SAS, 2000). Mean separation was performed using the Tukey's W-procedure (SAS, 2000).

3.3 Results

3.3.1 Summary statistics

Table 3.2 shows the number of observations, raw means, standard deviations, minimum and maximum values for the farrowing interval, farrowing index, gestation length, number of services per conception, total number of piglets born, number of piglets born alive, number of piglets born dead, total birth weight and average birth weight of the traits assessed in this study. The gestation lengths of the sows had a range of 28 days. Table 3.3 summarises the levels of significance of each of the fixed effects or covariates from the analyses. Genotype, parity of sow, season of farrowing and genotype × season interaction, all significantly affected ($P<0.05$) IBWT.

3.3.2 Number of matings, farrowing intervals and farrowing indices

The mean number of matings per conception was 1.29, with a coefficient of variation of 34 %. Parity of sow significantly influenced ($P<0.05$) the number of services per conception. The year of farrowing and month had no effect ($P>0.05$) on number of matings per conception. The influence of parity on number of matings in Mukota sows is shown in Tables 3.4. In general, the number of matings per conception decreased ($P<0.05$) with an increase in parity up to parity 7, then increased in parity 8.

Table 3.2: Summary statistics of farrowing interval, farrowing index, gestation length, number of matings, total number of piglets born, number of piglets born alive, number of piglets born dead, total, average and individual birth weights

Variable	N	Mean	SD	Minimum	Maximum
Farrowing interval (days)	431	155.8	13.90	123.0	220.0
Farrowing index	431	2.4	0.20	1.7	3.0
Gestation length (days)	427	114.3	3.40	99.0	127.0
Number of matings per conception	431	1.3	0.50	1.0	4.0
Total number born	434	8.0	2.18	3.0	13.0
Number born alive	434	7.1	2.29	1.0	12.0
Number born dead	434	0.8	1.28	0.0	6.0
Total litter birth weight (kg)	433	5.5	3.33	0.4	13.2
Average litter birth weight (kg)	433	0.8	0.23	0.4	1.5
Individual birth weight (kg)	3107	1.0	0.45	0.3	1.7

N: sample size; SD: standard deviation

Table 3.3: Summary of the levels of significance for the fixed factors and covariates included in the analyses

	Main factors						Interactions				Covariates				
Variable	G	P	S	M	L	R	G × S	G × P	G × M	G × R	β_1	β_2	β_3	β_4	β_5
NOMTG		**													
GLNTH	*														
FI		*										*			
FX		*										*			
TBWT	**	*	*					**							**
AVBWT	**	*	*		*		*								**
NBT		*					*				*				
NBA	*	*	*				*								
NBD			*		*		*								
IBWT	**					*				**					

Abbreviations: NOMTG: number of services per conception, GLNTH: gestation length, FI: farrowing interval, FX: farrowing index, TBWT: total litter weight, AVBWT: average birth weight, NBT: total number of pigs born, NBA: number of pigs born alive, NBD: number born dead, IBWT: individual birth weight; G: breed of sire, P: parity, S: month of farrowing, M: season of mating, L: year of farrowing, R: sex of pig, β_1: TBWT, β_2: GLNTH, β_3: NBT, β_4: FI, β_5: NBA. * $P<0.05$, **$P<0.01$

Table 3.4: Number of matings per conception (± standard error) in Mukota sows

Parity	N	Number of matings per conception
1	58	1.62 ± 0.02^{f}
2	53	1.38 ± 0.03^{d}
3	51	1.20 ± 0.04^{bc}
4	58	1.15 ± 0.02^{ab}
5	46	1.13 ± 0.05^{a}
6	49	1.23 ± 0.04^{c}
7	60	1.10 ± 0.03^{a}
8	56	1.51 ± 0.03^{e}

^{abcdef}Values with different superscripts are statistically different ($P<0.05$).

The least square mean gestation length for the herd was 114.3 days, with a coefficient of variation of 2.72 days. Except pig genotype, all the other fixed effects were not significant in influencing gestation length, except the total birth weight and the number of piglets born alive as covariates ($P<0.05$). The gestation lengths were 115.0 ± 0.523 and 113.7 ± 0.494 days in sows mated to Large White and Mukota genotypes, respectively. The mean farrowing interval was 156 days and the coefficient of variation was 8.02 days. Parity of the sow and the length of the preceding gestation, which was incorporated into the model as a covariate, significantly influenced ($P<0.05$) the farrowing interval. The year of farrowing did not affect ($P>0.05$) farrowing intervals.

The mean farrowing index was 2.35. The gestation length, which was also incorporated as a covariate, significantly influenced ($P<0.05$) farrowing indices. Parity of the sow influenced ($P<0.05$) the farrowing index. The influence of parity on the farrowing index is shown in Table 3.5. The farrowing index was high during the first two parities and was low in later parities.

The mean TBWT was 5.58 kg, while the mean AVBWT was 0.78 kg. The genotype of pig significantly influenced ($P<0.05$) the weight of pigs at birth. Parity of sow affected both TBWT and AVBWT ($P<0.05$). There were also significant interactions of parity and genotype ($P<0.05$) on both AVBWT and TBWT. Month of farrowing significantly influenced ($P<0.05$) both variables. The NBA, used as a covariate, was significant ($P<0.05$) in influencing TBWT, but not on AVBWT. The influence of parity of sow on AVBWT and TBWT is shown in Tables 3.6. The total weight of pigs at birth was low in

Table 3.5: Effect of parity effects on farrowing index in Mukota sows

Parity	N	Farrowing index
1	42	2.52 ± 0.017^{c}
2	62	2.49 ± 0.025^{c}
3	56	2.28 ± 0.029^{a}
4	53	2.40 ± 0.031^{b}
5	58	2.41 ± 0.034^{b}
6	56	2.41 ± 0.019^{b}
7	55	2.34 ± 0.023^{a}
8	49	2.27 ± 0.024^{a}

^{abc} Values with different superscripts are statistically different ($P<0.05$).

Table 3.6: Effects of parity on litter weight (TBWT) and average weight at birth (AVBWT) in Mukota sows

Parity	N	TBWT	AVBWT
1	58	4.60 ± 0.440^{a}	0.72 ± 0.026^{a}
2	53	4.91 ± 0.535^{a}	0.72 ± 0.027^{a}
3	51	6.12 ± 0.381^{b}	0.82 ± 0.044^{c}
4	58	6.00 ± 0.333^{b}	0.81 ± 0.011^{bc}
5	46	6.24 ± 0.295^{b}	0.82 ± 0.028^{c}
6	49	5.89 ± 0.388^{ab}	0.80 ± 0.016^{bc}
7	60	5.53 ± 0.411^{ab}	0.78 ± 0.021^{b}
8	56	6.64 ± 0.399^{b}	0.84 ± 0.032^{d}

^{abc} Values with different superscripts within column are statistically different ($P<0.05$).

the first two parities and increased from parity 3. Table 3.7 shows the influence of month of farrowing on the weights at birth. The month of July had high values TBWT, AVBWT, NBA and NBT. The AVBWT was also highest during the rainy season (November to January) ($P<0.05$). Litter size (NBA and NBT) was high during the cold months of May to July and also in December ($P<0.05$). Table 3.8 shows the influence of breed of boar on reproductive parameters. Sows mated to Large White boars produced heavier litters than those mated to Mukota boars ($P<0.05$). The influence of parity on TBWT and AVBWT for the Mukota and LW × Mukota crossbred pigs is shown in Table 3.9. The TBWT increased more than two-fold as parity increased in sows mated to Large White boars.

3.3.3 Total and average weights at birth

Table 3.10 shows the influence of month of farrowing and genotype of piglets on TBWT and AVBWT in sows mated to Mukota and large White boars. The mean TBWT for the Mukota and the Large White × Mukota crossbred pigs were 4.70 and 7.94 kg, respectively ($P<0.05$). July and August had the highest TBWT and AVBWT for both genotypes ($P<0.05$). There was a significant sex × genotype interaction on IBWT ($P<0.05$) (Table 3.11). The respective IBWT were 0.77 and 1.14 kg for Mukota and the Large White × Mukota crossbred pigs. There was a significant ($P<0.05$) interaction between piglet genotype and season of farrowing.

Table 3.7: Influence of month of farrowing on litter birth weight (TBWT), average birth weight (AVBWT), total number born (NBT) and number born alive (NBA)

Month	N	TBWT	AVBWT	NBA	NBT
January	36	5.63 ± 0.627^{b}	0.80 ± 0.287^{ab}	7.18 ± 0.417^{a}	7.82 ± 0.247^{ab}
February	36	4.64 ± 0.237^{ab}	0.73 ± 0.442^{a}	6.71 ± 0.237^{a}	7.41 ± 0.432^{a}
March	43	4.69 ± 0.256^{ab}	0.69 ± 0.143^{a}	6.59 ± 0.456^{a}	7.63 ± 0.343^{a}
April	45	4.44 ± 0.576^{ab}	0.75 ± 0.384^{a}	6.09 ± 0.376^{a}	7.53 ± 0.344^{a}
May	34	5.70 ± 0.417^{b}	0.76 ± 0.230^{a}	7.97 ± 0.431^{b}	7.99 ± 0.650^{ab}
June	37	5.43 ± 0.459^{ab}	0.78 ± 0.387^{a}	7.07 ± 0.459^{ab}	8.65 ± 0.487^{b}
July	32	7.57 ± 0.745^{c}	0.91 ± 0.238^{b}	8.05 ± 0.345^{b}	8.70 ± 0.438^{b}
August	33	6.75 ± 0.564^{bc}	0.63 ± 0.143^{a}	6.30 ± 0.564^{a}	6.94 ± 0.345^{a}
September	32	4.15 ± 0.773^{a}	0.64 ± 0.479^{a}	6.31 ± 0.573^{a}	7.18 ± 0.543^{a}
October	34	5.45 ± 0.542^{b}	0.81 ± 0.301^{ab}	7.47 ± 0.542^{b}	7.89 ± 0.155^{a}
November	34	6.75 ± 0.447^{bc}	0.96 ± 0.165^{c}	6.65 ± 0.247^{a}	7.59 ± 0.365^{a}
December	35	7.68 ± 0.687^{c}	0.98 ± 0.375^{c}	7.18 ± 0.571^{a}	8.16 ± 0.375^{b}

^{abc} Values with different superscripts within column are statistically different ($P<0.05$).

Table 3.8: Litter weight (TBWT), average birth weight (AVBWT), total number of pigs born (NBT), pigs born alive (NBA) and number of pigs born dead (NBD) in sows mated to Mukota and Large White boars

	Breed of boar	
Trait	Mukota	Large White
TBWT	4.80 ± 0.418^{a}	7.84 ± 0.861^{b}
AVBWT	0.70 ± 0.042^{a}	0.99 ± 0.068^{b}
NBT	7.53 ± 0.453^{a}	8.52 ± 0.421^{b}
NBA	6.75 ± 0.171^{a}	7.61 ± 0.196^{b}
NBD	0.78 ± 0.033	0.91 ± 0.045

^{ab} Values with different superscripts within row are statistically different ($P<0.05$).

Table 3.9: Influence of parity of sow on TBWT in Mukota sows mated to Mukota and Large White boars

		Breed of boar		
Parity	N	Mukota	N	Large White
1	36	4.14 ± 0.304^{a}	16	5.30 ± 0.304^{b}
2	48	4.30 ± 0.344^{a}	15	7.02 ± 0.300^{c}
3	43	5.05 ± 0.341^{ab}	13	8.78 ± 0.541^{d}
4	44	5.27 ± 0.298^{b}	10	8.90 ± 0.457^{d}
5	46	5.59 ± 0.346^{b}	12	9.10 ± 0.578^{de}
6	43	5.38 ± 0.234^{b}	13	9.44 ± 0.613^{e}
7	48	6.91 ± 0.320^{c}	13	14.36 ± 0.652^{f}
8	38	6.73 ± 0.230^{c}	12	10.21 ± 0.567^{e}

^{abcdef} Values with different superscripts are statistically different ($P<0.05$).

Table 3.10: Influence of month of farrowing and genotype on total and average weights at birth in sows mated to Mukota and Large White (LW) boars

	TBWT				AVBWT			
	N	Mukota	N	LW	N	Mukota	N	LW
January	30	4.18^{b}	6	9.27^{c}	30	0.70^{ab}	6	0.97^{ab}
February	24	4.60^{bc}	12	8.44^{b}	24	0.74^{b}	12	0.94^{ab}
March	35	4.49^{b}	6	7.45^{a}	35	0.68^{a}	6	0.89^{a}
April	35	3.94^{a}	10	7.45^{a}	35	0.66^{a}	10	1.15^{b}
May	26	5.55^{c}	6	7.51^{a}	26	0.70^{ab}	6	0.88^{a}
June	22	4.17^{b}	12	7.25^{a}	22	0.66^{a}	12	0.78^{a}
July	21	5.85^{c}	15	10.00^{c}	21	0.78^{b}	15	1.08^{b}
August	18	6.44^{d}	13	8.49^{b}	18	0.65^{a}	13	1.12^{b}
September	17	4.38^{b}	14	9.10^{c}	17	0.66^{a}	14	0.89^{a}
October	22	5.26^{c}	12	8.48^{b}	22	0.72^{b}	12	0.84^{a}
November	21	4.89^{bc}	13	8.93^{bc}	21	0.74^{b}	13	0.97^{ab}
December	24	4.87^{bc}	11	7.17^{a}	24	0.69^{a}	11	0.95^{a}

^{abc} Values with different superscripts within column are statistically different ($P<0.05$). The standard error for TBWT ranged from 0.458 to 0.712, while those for AVBWT ranged from 0.032 to 0.045.

Table 3.11: Interaction of sex and genotype on individual piglet birth weight (IBWT)

Breed of boar	Sex	N	IBWT (kg)
Mukota	Male	1237	0.79 ± 0.005^{a}
Mukota	Female	1230	0.76 ± 0.008^{b}
Large White	Male	340	1.12 ± 0.011^{c}
Large White	Female	300	1.16 ± 0.010^{d}

^{abcd} Values with different superscripts are statistically different ($P<0.05$).

3.3.4 Total number of pigs born, number born alive and number born dead

The mean NBT was 7.62 piglets per sow. Genotype of pig and parity were the only factors that significantly ($P<0.05$) influenced NBT and NBA. Parity of sow and genotype, however, did not affect NBD. Season of farrowing had no effect ($P>0.05$) on litter size. The mean NBA and NBD was 6.86 and 0.77, respectively. There were differences ($P<0.05$) between the NBA in sows mated to Mukota or Large White boars (Table 3.8). The influence of parity of sow on NBT, NBA and NBD is depicted in Table 3.12. The highest NBT and NBA values were obtained in parity 6 sows sired by Large White boars. In Mukota sows sired by Mukota boars, however, the highest NBT was observed was observed at parity 7 while highest NBA was in parity 4. Table 3.13 shows the influence of month of farrowing on NBA in sows mated to Mukota and Large White boars. There was a significant interaction between genotype and month on NBA ($P<0.05$).

3.3.5 Relationships among traits

Significant ($P<0.05$) positive linear correlation coefficients were detected between NBA versus TBWT ($r = 0.60$; $P<0.05$), NBA versus AVBWT ($r = 0.41$; $P<0.05$) and between AVBWT and TBWT ($r = 0.58$; $P<0.05$). A negative relationship between TBWT and GLNTH ($r = -0.32$; $P<0.05$) was also observed.

Table 3.12: Influence of parity of sow on total number born (NBT), number born alive (NBA) and number born dead (NBD)

Parity	N	NBT	NBA	NBD
1	42	5.46 ± 0.564^{a}	4.96 ± 0.407^{a}	0.50 ± 0.278
2	62	7.18 ± 0.441^{b}	6.73 ± 0.343^{b}	0.45 ± 0.030
3	56	8.24 ± 0.560^{c}	7.52 ± 0.461^{c}	0.71 ± 0.023
4	53	8.45 ± 0.662^{cd}	7.80 ± 0.405^{c}	0.65 ± 0.015
5	58	8.47 ± 0.685^{c}	7.53 ± 0.374^{c}	1.00 ± 0.010
6	56	8.86 ± 0.714^{d}	7.00 ± 0.485^{c}	1.85 ± 0.062
7	55	8.14 ± 0.573^{c}	6.71 ± 0.387^{b}	1.43 ± 0.041
8	49	8.40 ± 0.648^{cd}	8.20 ± 0.488^{c}	0.20 ± 0.033

^{abcd} Values with different superscripts within column are statistically different ($P<0.05$).

Table 3.13: Influence of month of farrowing on number of live pigs at birth (NBA) in sows mated to Mukota and Large White boars

Month	N	Mukota	N	Large White
January	30	6.02 ± 0.361^{a}	6	9.27 ± 0.354^{b}
February	24	6.77 ± 0.452^{a}	12	8.44 ± 0.358^{b}
March	35	4.49 ± 0.356^{a}	6	7.45 ± 0.433^{ab}
April	35	3.94 ± 0.381^{a}	10	7.45 ± 0.343^{a}
May	26	5.55 ± 0.391^{b}	6	7.51 ± 0.325^{a}
June	22	4.17 ± 0.341^{a}	12	7.25 ± 0.425^{a}
July	21	5.85 ± 0.347^{ab}	15	10.00 ± 0.351^{b}
August	18	6.44 ± 0.352^{a}	13	8.49 ± 0.412^{ab}
September	17	4.38 ± 0.352^{a}	14	9.10 ± 0.257^{a}
October	22	5.26 ± 0.352^{ab}	12	8.48 ± 0.343^{a}
November	21	4.89 ± 0.354^{b}	13	8.93 ± 0.402^{b}
December	24	4.87 ± 0.321^{b}	11	7.17 ± 0.235^{a}

^{ab} Values with different superscript within column are statistically different ($P<0.05$).

3.4 Discussion

The objective of this study was to evaluate the reproductive performance of Mukota pigs and the litter traits when Mukota sows are mated to either Mukota or Large White boars. The pigs were raised on fibrous diets, which contained a high proportion of maize cobs. Purebred Large White pigs were not used in this study as preliminary studies had shown that large White piglets had poor survivability when fed on fibrous diets.

The mean number of matings that was observed in this study was comparable to those observed in Large White pigs raised under temperate environments (Gordon, 1997). The fairly few matings required for successful service and fertilization suggests that in Mukota sows, repeat breeders are few. Repeat breeding, which is, usually, a sign of presence of stress factors, suggests that these sows are tolerant to high stress levels. The observation that month of the year had no effect on the number of services per conception could suggest that the influence of heat stress on the exhibition of oestrus in Mukota sows is considerably low. In temperate breeds, heat stress results in sows exhibiting silent oestrus (Gordon, 1997; Mungate *et al*., 1999). Such findings suggest the need for using Mukota pigs in production environments that experience high ambient temperatures. The sows in this study were not sprinkled with water as is usually done with imported breeds (Mungate *et al*., 1999). The decrease in the number of matings per conception as parity of the sow advanced was not unexpected. In gilts, oestrus is difficult to detect than in mature sows. More information in determining the factors that influence exhibition of oestrus in Mukota sows, particularly in gilts, is required.

The gestation period observed in this study agrees with Holness (1972), who reported gestation lengths of 113 to 138 days for Mukota sows. The shorter gestation lengths in sows carrying the Mukota genotype agree with findings with the indigenous Desi pigs of India (Kumar *et al*., 1990) and indigenous Nigerian sows (Adebambo, 1986). Our observations are also in agreement with Singh and co-workers (1990), who reported that Desi sows that had been mated to Large White boars had longer gestation periods than those mated to local boars. The farrowing intervals and farrowing indices were within the expected ranges (Gordon, 1997). The high farrowing index observed during the first two parities is probably due to the difficulty in detecting sows exhibiting oestrus, thereby increasing the mean farrowing intervals.

The large birth weights in sows mated to Large White boars compared to Mukota boars suggest that there is possible hybrid vigour on birth weight. The higher weights of pigs born of Large White sires indicate the superiority of the imported blood on litter weight, as also reported by Pathiraja (1986). Piglet birth weight increases with crossbreeding (Maburutse, 1992; Mungate *et al*., 1999). The average birth weight of the crossbred pigs was higher than for Mukota. The average birth weight of Large White pigs in Zimbabwe, when fed on conventional diets with low fibre content, is higher than those observed in Mukota and crossbred pigs. Mungate and co-workers (1999) reported an average birth weight of 1.44 kg. The average and total birth weights for the Mukota piglets are comparable to the Meishan piglets reported by Haley and co-workers (1992), but are lower than those of Large White pigs. The weights are, however, higher than those reported for the indigenous Desi pigs of India (Kumar *et al*., 1990). In temperate breeds, low birth weight is associated with low post-natal growth rates and even low chances of survival to weaning. There is, therefore, need to evaluate post-natal performance of the Mukota pigs. In the extensive production systems, post-natal growth rate appears to be more important than litter size, since the piglets are almost always exposed to vagaries of the weather. Pigs with faster growth rates are, therefore, more likely to withstand the draughts than their weaker counterparts. The low birth weights in gilts than sows observed in this study are consistent with literature (Whittemore, 1993; Perskovicova *et al*., 2002). Gilts produce piglets of low birth weights because they are still physiologically immature and hence have to partition nutrients between their own nutrient requirements and those of the foetuses. On the other hand, old sows tend to undergo a physiological deterioration and may not utilise their feed resources most efficiently in providing nutrition to foetuses in *utero* (Whittemore, 1993). In this study, Mukota boars served Mukota gilts and Large White boars were mated to older sows. There was, therefore, possible confounding between these factors, which could not be separated.

The low litter size observed in the Mukota sows mated to Mukota boars agrees with literature (Adebambo, 1986; Holness, 1991; Ncube *et al*., 2003). This might be due to a higher embryonic or foetal mortality resulting from small body size of the piglets. This could suggest that the higher litter size in sows mated to Large White boars might be due to reduced embryonic death or foetal mortality in crossbred piglets due to increased prenatal weight gain. It is also possible that Large White boars had better fertilization capacity (Pandey *et al*., 1996). They have been selected for reproductive capacity and the

Mukota have not. The higher litter size and NBA in sows mated to LW boars indicates that crossbred pigs could be used in smallholder pig production systems to increase reproductive efficiency. Recently, Chen and co-workers (2003), working with Yorkshire, Duroc, Hampshire and Landrace pigs, reported sufficiently large genetic variances for litter traits. Thus, although, litter traits have low heritabilities, it is possible to improve them through selection. It is important to evaluate the genetic variation in litter traits for the Mukota pigs, especially the weight traits. Crossbreeding is another possibility to increase litter size (Adebambo, 1986; Maburutse, 1992).

Holness (1991) concluded that the feed needed by one pig of an imported breed (e.g. Large White and Landrace) is sufficient for two and a half indigenous sows and a combined litter of 20 piglets (Holness, 1991). The observation that the NBA for Mukota sows was 6.75 would mean that the feed for one imported sow is equivalent to feeding Mukota sows that produce about 17 pigs. This was achieved with an unselected population of sows. Our observations indicate that selection could be effectively used to increase litter performance of Mukota pigs.

The influence of parity of sow on litter size in temperate breeds is well recognised (Mungate *et al*., 1999; Perskovicova *et al*., 2002; Chen *et al*., 2003). Mukota sows showed a steady increase in litter size up to parity 7, possibly suggesting that the low litter size in Mukota sows, like in any other breed, could partly be because of limitation in the uterine capacity. It has been shown that the second and subsequent parities often result in more pigs than the first parity litters. In genetic analyses, the first and subsequent parities are regarded as different traits. Mungate and co-workers (1999) suggested that gilts produce fewer fertile ova compared to mature sows. Older sows, however, tend to have a higher incidence of farrowing problems, such as dystocia, resulting in higher piglet mortalities. Another reason for the reduced litters at advanced parities is the reduction in muscle tone (Whittemore, 1993), which sets in as the sow gets older. No major farrowing difficulties were experienced with the pigs in this study. In a survey conducted in a communal area in north-eastern Zimbabwe, Mashatise (2002) reported that the smallholder farmers do not attach much value to the size of the litter, but to the vitality of the piglets produced. The farmers, actually, cull sows at parity 2, arguing they would want to consume the sows, in addition to the growing pigs. This further confirms that genetic improvement in the local pigs should target improving birth weights, rather than litter size, although these traits are generally reported to be antagonistic to each other (Mungate *et al*., 1999). The positive correlation between NBA and TBWT was expected. The positive correlation between NBA and AVBWT also suggest that there is potential to increase litter size in the Mukota sows.

3.5 Conclusions

It can be concluded that the number of matings per conception decreased with an increase in parity of the sow. The gestation length ranged from 99 to 127 days. Crossbred pigs had higher AVBWT and TBWT than Mukota pigs. Pig genotype and parity influenced NBT and NBA, AVBWT and TBWT. The NBT was lowest in the Mukota pigs and highest in sows mated to LW boars. The highest litter sizes were obtained in parities 6 and 7.

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Chapter 4: Non-Genetic Factors Affecting Pig performance at Three Weeks and at Weaning

Abstract

Data from 434 litters farrowed between January 1998 and August 2003 were used to evaluate the performance of Mukota and Large White × Mukota pigs up to the age of weaning. Pigs were weaned at 35 days (± 4 days). The traits studied were number of pigs at 21 days of age (LSTHR), total weight of pigs at 21 days of age (TWTHR), ADG to 21 days (ADGTHR), number of pigs weaned (LSWEAN) and weight at weaning (TWWT) and body weight gain to weaning (ADGWW). Other parameters computed were the weight gain from 21 to 35 days (ADG3TW) and pre-weaning mortality (PREWM). The mean LSTHR, LSWEAN, TWWT, AVWWT and ADGWW were 6.45, 6.20, 36.2, 5.9 and 0.17, respectively. The month of farrowing and breed of sire did not affect ($P > 0.05$) LSTHR. The overall body weight gain from birth to weaning was not influenced by sex of the pig. The weight of the piglets at three weeks for the Mukota and crossbred pigs were 2.24 and 3.15 kg, respectively. The ADGWW was similar ($P>0.05$) between Mukota and crossbred pigs. There was a consistent increase in TWWT as parity increased. At advanced parities, crossbred pigs had lower TWWT than purebred Mukota pigs. The mean mortality rate in the herd was 19 %. The mortality rates increased ($P<0.05$) up to the fifth parity and then declined. The highest mortality rates were observed for litters that were farrowed during the cold months.

4.1 Introduction

Mortality of pigs before weaning is critical to the performance of the herd. During this period, pigs are still developing acquired immunity and can also be crushed by their mothers. Mothering ability and growth performance of piglets are, thus, traits of economic importance in pig production systems. Weak piglets are not only susceptible to crushing, but are also less competitive during feeding than their stronger counterparts. This study seeks to evaluate the factors that influence performance of Mukota and crossbred pigs up to weaning.

Three-week performance is closely associated with the development of acquired immunity in a pig (Whittemore, 1993). Performance at this stage is, thus crucial to the overall growth of the pig and the resistance to diseases prevalent in a particular environment. Such data is available, though limited, on imported breeds (Mungate *et al*., 1999), but none on the local genotypes. Such information is vital in designing and evaluating crossbreeding schemes involving the local genotypes. With imported pigs, heavy pigs at weaning have been reported to have superior growth rates post-weaning (Mungate *et al*., 1999). It has, however, been established that Mukota are lighter at birth than imported breeds, such as the Large White (Ncube *et al*., 2003). The objective of the study was to determine the non-genetic factors influencing post-natal performance of Mukota and Large White × Mukota crossbred pigs up to weaning. This paper evaluates both sow traits and individual weight traits in Mukota and Large White × Mukota crossbred pigs.

4.2 Materials and Methods

4.2.1 Study site and pig population structure

The study site and the pig population structure were described in Section 3.2.1 and 3.2.2, respectively.

4.2.2 Mating, feeding and housing management

The management of the pigs was described in Section 3.2.3. No castration and creep feeding was practised and pigs were weaned at 35 days (± 4 days).

4.2.3 Data and traits analysed

Data were collected between January 1998 and August 2003. A total of 431 litters were evaluated. This comprised of 2467 and 640 individual pig records each of Mukota and Large White × Mukota crossbred pigs, respectively. Litter traits recorded at three weeks were the litter size (LSTHR) and the litter weight (THRWT). The average weight of pigs at three weeks (AVWTHR) was computed as a derivative of the THRWT. At weaning, the number of pigs (LSWEAN) and the total weight (TWWT) were recorded, with the average weight at weaning (AVWWT) also computed as a derivative. On individual weights of each pig, the average daily gain from birth to three weeks (ADGTHR), daily gain from three weeks to weaning (ADG3TW) and overall gain from birth to weaning (ADGWW) were calculated. Pre-weaning mortality (PREWM), defined as the proportion of pigs that died to the number of live pigs at birth (NBA), was also computed for each litter.

4.2.4 Statistical analyses

All traits were analysed using the generalised linear models procedures of the Statistical Analysis Systems (SAS, 2000). Fixed models with all possible first-order interactions were assumed. Models for final analysis were obtained after eliminating interactions that were not statistically significant ($P>0.05$). Before analyses, the variables LSTHR and LSWEAN were transformed using the square root transformation to normalise them. The least square means and their respective standard errors were back transformed in the presentation of results. The final models assumed for LSTHR (Model 1), THRWT (Model 2), AVWTHR (Model 3), ADGTHR (Model 4), LSWEAN (Model 5), TWWT (Model 6), AVWWT (Model 7), ADGTHR, ADG3TW and ADGWW (Model 8) and PREWM (Model 9) used were as follows:

Model 1: Litter size after three weeks of age

$Y_{ijkln} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_1 NBA + E_{ijklmn}$;

Model 2: Weight of pigs after three weeks

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_1 NBA + \beta_2 TBWT + E_{ijkl}$;

Model 3: Average weight at three weeks

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_3 AVBWT + E_{ijkl}$;

Model 4: Average daily gain from birth to three weeks

$Y_{ijklm} = \mu + G_i + P_j + S_k + R_l + (G \times S)_{ik} + (G \times P)_{ij} + \beta_3 AVBWT + E_{ijklm}$;

Model 5: Litter size at weaning

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_1 NBA + E_{ijkl}$;

Model 6: Total weight at weaning

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_4 LSWEAN + E_{ijkl}$;

Model 7: Average weight at weaning

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times S)_{ik} + \beta_1 NBA + E_{ijkl}$;

Model 8: Body weight gain up to weaning

$Y_{ijklm} = \mu + G_i + P_j + S_k + R_l + (G \times S)_{ik} + (G \times P)_{ij} + \beta_2 TBWT + E_{ijklm}$;

Model 9: Pre-weaning mortality

$Y_{ijkl} = \mu + G_i + P_j + S_k + (G \times S)_{ik} + (G \times P)_{ij} + \beta_3 AVBWT + E_{ijkl}$;

where:

Y_{ijklmn} = an observation

μ = overall mean response

G_i = fixed effect of the i^{th} genotype of pig

P_j = fixed effect of the j^{th} parity of dam

S_k = fixed effect of the k^{th} season at which trait was observed

R_l = fixed effect of sex of pig

$(G \times P)_{ij}$ = genotype × parity interaction

$(G \times S)_{ik}$ = genotype × season of weaning interaction

β_1 = partial linear regression coefficient of the dependent variable on NBA

β_2 = partial linear regression coefficient of the dependent variable on TBWT

β_3 = partial linear regression coefficient of the dependent variable on AVBWT

β_4 = partial linear regression coefficient of the dependent variable on LSWEAN

E_{ijklm} = residual error.

Mean separation was performed using the Tukey's procedure (SAS, 2000).

4.3 Results

4.3.1 Summary statistics and levels of significance of fixed factors

The summary statistics for the traits analysed are presented in Table 4.1. Pre-weaning mortality ranged from 0 to 70 percent. The litter size at weaning was 11, with a maximum litter weight of 81 kg (Table 4.1). The levels of significance of the fixed factors analysed for three-week and weaning performance are presented in Table 4.2. The season of farrowing and breed of sire did not affect ($P>0.05$) litter sizes at three weeks.

4.3.2 Litter sizes at three and five weeks

The NBA, which was incorporated as a covariate, significantly influenced litter size at three weeks ($P<0.05$). Both parity of sow and breed of sire did not influence LSTHR ($P>0.05$). As for LSTHR, breed of sire and parity of sow did not affect ($P>0.05$) number of pigs weaned. Table 4.3 shows the influence of month of weaning on litter size at weaning. May, June and July had the lowest ($P<0.05$) litter size at weaning. There was a significant interaction ($P<0.05$) between sire breed and month of weaning on LSWEAN.

4.3.3 Pre-weaning piglet mortality

Both parity of sow and month of weaning significantly affected ($P<0.05$) mortality. Breed of sire, however, did not influence ($P>0.05$) mortality from birth to weaning. The mean mortality rate in the herd was 0.19. As shown in Table 4.4, the mortality rates increased ($P<0.05$) up to the fifth parity and then tended to decrease as parity increased thereafter. The highest mortality rates were observed for litters that were farrowed during the cool months of the year (Table 4.5).

Table 4.1: Summary statistics for the number (LSTHR) and the total weight (THRWT) at three weeks, number of pigs weaned (LSWEAN), litter weight at weaning (TWWT), average weight at weaning (AVWWT), average daily gain from birth to three weeks (ADGTHR), daily gain from three to five weeks (ADG3TW), gain from birth to weaning (ADGWW) and pre-weaning mortality (PREWM) in piglets across the two genotypes

Trait	N	Mean	SD	Minimum	Maximum
LSTHR	433	6.45	2.85	3.0	12.0
LSWEAN	433	6.20	2.56	1.0	11.0
TWWT (kg)	433	36.15	16.52	7.4	81.0
AVWWT (kg)	433	5.86	1.38	2.7	9.0
PREWM (%)	433	9.57	1.55	0.00	0.65
THRWT (kg)	3107	3.15	0.98	0.8	7.5
ADGTHR (kg/day)	3107	0.13	0.45	0.0	0.2
ADG3TW (kg)	3107	0.22	0.12	0.2	0.3
ADGWW (kg/day)	3107	0.17	0.86	0.1	0.3

N: sample size; SD: standard deviation.

Table 4.2: Significance levels of the factors and covariates included in the analyses across genotypes

	Main effects				Interactions		Covariates			
Variable	G	P	S	R	G × S	G × P	β_1	β_2	β_3	β_4
LSTHR (kg)							*			
THRWT (kg)	**			*			*	*		
AVWTHR (kg)	**								*	
ADGTHR (kg)	***			*						*
LSWEAN			*		*		*			
TWWT (kg)	***	*	*			*				*
AVWWT (kg)	***	*	*				*			
ADG3TW (kg)								*		
ADGWW (kg)									*	
PREWM (%)		*	*							

Abbreviations: LSTHR: number of pigs at three weeks, THRWT: litter weight at three weeks, AVWTHR: average weight at three weeks, ADGTHR: average daily gain from birth to three weeks, LSWEAN: number of pigs weaned, TWWT: litter weight at weaning, AVWWT: average weaning weight, ADG3TW: daily gain from three weeks to weaning, ADGWW: gain from birth to weaning, PREWM: pre-weaning mortality.

G: genotype, P: parity, S: month of farrowing, R: sex of pig, β_1: number born alive (NBA), β_2: total litter weight at birth (TBWT), β_3: average birth weight (AVBWT), β_4: LSWEAN.

*P<0.05, **P<0.01 ***P<0.001

Table 4.3: Influence of month of weaning on litter size at weaning in sows

		Breed of sire		
Month	N	Mukota	N	Large White
January	30	7.4 ± 0.57^{b}	6	6.5 ± 0.97^{a}
February	24	7.4 ± 1.15^{b}	12	7.5 ± 1.28^{b}
March	35	7.1 ± 0.57^{b}	6	7.5 ± 1.34^{b}
April	35	6.4 ± 0.66^{ab}	10	6.7 ± 0.58^{a}
May	26	5.7 ± 0.35^{a}	6	6.2 ± 0.79^{a}
June	22	5.8 ± 0.46^{a}	12	6.1 ± 0.79^{a}
July	21	5.9 ± 0.34^{a}	15	6.3 ± 0.79^{a}
August	18	6.5 ± 0.56^{ab}	13	6.5 ± 0.26^{a}
September	17	6.7 ± 1.24^{ab}	14	6.6 ± 0.55^{a}
October	22	6.5 ± 0.56^{ab}	12	6.1 ± 0.35^{a}
November	21	7.2 ± 0.47^{b}	13	7.5 ± 0.23^{b}
December	24	6.9 ± 0.37^{b}	11	7.5 ± 0.35^{b}

^{ab} Values with different superscripts within column are statistically different ($P<0.05$).

Table 4.4: Influence of parity of sow on pre-weaning mortality (%) in sows mated to Mukota and Large White sires

	Breed of sire			
Parity	N	Mukota	N	Large White
1	36	11.3^{a}	16	20.6^{a}
2	48	23.3^{b}	15	28.5^{b}
3	43	25.1^{b}	13	22.6^{a}
4	44	29.0^{c}	10	30.4^{b}
5	46	36.5^{d}	12	32.7^{b}
6	43	25.7^{b}	13	30.6^{b}
7	48	24.6^{b}	13	24.7^{a}
8	38	23.2^{b}	12	22.8^{a}
Standard error		2.43		2.32

^{ab} Values with different superscripts within column are different ($P<0.05$).

Table 4.5: Influence of month of weaning on pre-weaning mortality (%) in sows mated to Mukota and Large White boars

Month	N	Mukota	N	Large White
January	30	19.1^{a}	6	22.5^{a}
February	24	17.3^{a}	12	25.5^{a}
March	35	12.2^{a}	6	26.8^{a}
April	35	16.3^{a}	10	29.6^{a}
May	26	26.4^{b}	6	33.6^{ab}
June	22	28.4^{b}	12	37.0^{b}
July	21	25.5^{b}	15	31.6^{a}
August	18	23.6^{ab}	13	32.6^{a}
September	17	11.8^{a}	14	16.5^{a}
October	22	12.0^{a}	12	24.5^{a}
November	21	18.8^{a}	13	16.7^{a}
December	24	18.5^{a}	11	21.7^{a}
Standard error		2.45		2.05

^{ab} Values with different superscripts within column are different ($P<0.05$).

4.3.4 Body weights and body weight gains from birth to weaning

Both ADGTHR and THRWT were influenced by the genotype and sex of the pig ($P<0.05$). The weight of the piglets at birth, which was incorporated into the model as a covariate, also significantly ($P<0.05$) influenced the weight of the piglets at three weeks. Parity of sow had no influence on the weight traits at three weeks. However, TBWT and NBA, when incorporated into the model as covariates, significantly ($P<0.05$) influenced both ADGTHR and THRWT. Table 4.6 shows the influence of sex on the body weight and body weight gain in purebred indigenous Mukota and crossbred pigs at three weeks of age. In general, crossbred pigs gained body weights faster ($P<0.05$) than Mukota pigs up to three weeks of age. As shown in Table 4.7, month of farrowing significantly ($P<0.05$) influenced both ADGTHR and THRWT. Growth rates were lowest in the cold months ($P<0.05$) and highest ($P<0.05$) from November to January.

Breed of sire and the parity of the sow influenced ($P<0.05$) TWWT. The litter size at weaning per sow, which was incorporated as a covariate, also significantly affected ($P<0.05$) the TWWT. The season of weaning had no effect ($P>0.05$) on TWWT. The influence of parity on TWWT within the Mukota and crossbred pigs is illustrated in Table 4.8. There was a steady and consistent increase ($P<0.05$) in TWWT as parity increased. Table 4.9 shows the influence of parity within each genotype. At advanced parities, crossbred pigs had lower TWWT than purebred Mukota pigs.

Table 4.6: Least square means (± standard error) of sex and genotype on body weight gain from birth to three weeks (ADGTHR) and body weight at three weeks (THRWT)

Breed of sire	Sex	N	ADGTHR (kg/day)	THRWT (kg/day)
Mukota	Male	1237	0.11 ± 0.026^{a}	2.34 ± 0.256^{b}
Mukota	Female	1230	0.10 ± 0.029^{a}	2.14 ± 0.215^{a}
Large White	Male	340	0.15 ± 0.045^{b}	3.20 ± 0.245^{c}
Large White	Female	300	0.14 ± 0.041^{b}	2.91 ± 0.262^{c}

^{abc} Values with different superscripts within column are significantly different ($P<0.05$).

Table 4.7: Effect of month of farrowing on body weight gain from birth to three weeks (ADGTHR) and body weight at three weeks (THRWT) across the two genotypes

Month	N	ADGTHR (kg/day)	THRWT (kg/day)
January	261	0.15 ± 0.019^{b}	3.14 ± 0.213^{b}
February	260	0.13 ± 0.019^{b}	3.02 ± 0.214^{b}
March	267	0.10 ± 0.018^{a}	2.21 ± 0.244^{a}
April	255	0.11 ± 0.026^{a}	2.05 ± 0.578^{a}
May	254	0.09 ± 0.027^{a}	2.14 ± 0.510^{a}
June	260	0.08 ± 0.019^{b}	2.02 ± 0.212^{a}
July	259	0.07 ± 0.019^{a}	2.01 ± 0.222^{a}
August	235	0.07 ± 0.024^{a}	2.03 ± 0.553^{a}
September	258	0.09 ± 0.020^{a}	2.14 ± 0.217^{a}
October	267	0.09 ± 0.018^{a}	2.12 ± 0.245^{a}
November	258	0.12 ± 0.021^{ab}	2.89 ± 0.462^{a}
December	270	0.14 ± 0.017^{b}	3.04 ± 0.241^{ab}

^{ab} Values with different superscripts within column are significantly different ($P<0.05$).

Table 4.8: Influence of parity on total weaning weight (TWWT) and average weaning weight (AVWWT) across the two genotypes

Parity	N	TWWT (kg)	AVWWT (kg)
1	42	25.8 ± 3.41^{a}	5.0 ± 0.37^{a}
2	62	28.2 ± 3.40^{a}	5.3 ± 0.38^{a}
3	56	29.4 ± 3.21^{a}	5.4 ± 0.39^{a}
4	53	33.1 ± 3.34^{ab}	5.6 ± 0.33^{ab}
5	58	35.7 ± 3.23^{b}	5.7 ± 0.37^{b}
6	56	38.8 ± 3.24^{b}	6.0 ± 0.35^{b}
7	55	39.7 ± 3.20^{b}	6.0 ± 0.36^{b}
8	49	50.5 ± 3.65^{c}	7.5 ± 0.35^{c}

^{ab} Values with different superscripts within column are significantly different ($P<0.05$).

Table 4.9: Influence of parity and breed of sire (Mukota or Large White) on litter weight at weaning (TWWT) and average weight at weaning (AVWWT)

	TWWT (kg)				AVWWT (kg)			
Parity	N	Mukota	N	Large White	N	Mukota	N	Large White
1	36	27.6 ± 3.39^{a}	16	24.0 ± 3.43^{a}	36	5.1 ± 0.36^{a}	16	4.8 ± 0.38^{a}
2	48	32.1 ± 3.31^{a}	15	24.2 ± 3.43^{a}	48	5.6 ± 0.38^{a}	15	4.9 ± 0.38^{a}
3	43	27.6 ± 3.39^{a}	13	31.1 ± 4.19^{b}	43	5.7 ± 0.38^{a}	13	5.1 ± 0.41^{b}
4	44	32.1 ± 3.31^{a}	10	34.1 ± 3.43^{b}	44	6.0 ± 0.33^{a}	10	5.2 ± 0.33^{b}
5	46	36.7 ± 3.39^{ab}	12	34.7 ± 4.14^{b}	46	6.0 ± 0.33^{ab}	12	5.4 ± 0.42^{b}
6	43	38.9 ± 3.39^{ab}	13	38.7 ± 4.19^{b}	43	6.2 ± 0.33^{ab}	13	5.7 ± 0.41^{b}
7	48	39.6 ± 3.21^{b}	13	39.8 ± 4.19^{b}	48	6.3 ± 0.40^{b}	13	5.7 ± 0.34^{b}
8	38	56.3 ± 3.32^{c}	12	44.7 ± 4.15^{c}	38	8.3 ± 0.36^{c}	12	6.6 ± 0.34^{c}

^{abc} Values with different superscripts within column are significantly different ($P<0.05$).

The average weaning weight for all the pigs was 5.8 kg. Breed of sire affected ($P<0.05$) AVWWT (Table 4.9), which increased ($P<0.05$) with parity. As shown in Table 4.10, month of weaning significantly affected ($P>0.05$) both TWWT and AVWWT. The ADG3TW and ADGWW was not influenced ($P>0.05$) by sex, parity and breed of sire ($P>0.05$). The birth weight, incorporated as covariates, influenced ($P<0.05$) ADG3TW and ADGWW. The ADGWW for Mukota males, Mukota females, crossbred males and crossbred females were 0.17 ± 0.034, 0.16 ± 0.035, 0.18 ± 0.043 and 0.18 ± 0.044 kg, respectively.

4.4 Discussion

Within a genotype, the performance of pigs before weaning is largely a measure of the level of management on the farm (Whittemore, 1993). Growth of pigs from birth indicates, among other things, the mothering ability of the nurse sow and the ability of the pigs to adjust to the feed. Under smallholder pig production conditions, where the level of management is low, sow performance and the growth of the pigs is crucial. This is particularly so in production systems where farrowing crates are not employed to reduce piglet mortality. Compared to exotic breeds (Mungate *et al.*, 1999), performance of sows did not decline after the 6th parity, suggesting that the optimum time of culling for Mukota pigs needs to be determined. Sows in this study were fed on brood sow meal, which is different from what pigs under smallholder conditions get. This was necessitated by the unavailability of feeding resources that smallholder farmers use. The high mortality was high across all breeds and parities could be attributed to lack of heat and farrowing crates, since all other aspects of pig management were followed.

Table 4.10: Influence of month of weaning on the total weight at weaning (TWWT) and average weight at weaning (AVWWT) across the two genotypes

Month	N	TWWT (kg)	AVWWT (kg)
January	36	37.9 ± 3.14^{b}	6.1 ± 0.23^{b}
February	36	36.3 ± 3.14^{b}	6.0 ± 0.23^{b}
March	43	41.2 ± 3.12^{c}	6.4 ± 0.21^{c}
April	45	40.2 ± 3.17^{bc}	6.2 ± 0.33^{bc}
May	34	39.2 ± 3.25^{b}	5.8 ± 0.33^{b}
June	37	36.2 ± 3.22^{b}	5.7 ± 0.32^{ab}
July	32	34.2 ± 3.34^{ab}	5.4 ± 0.34^{a}
August	33	33.9 ± 3.39^{ab}	5.3 ± 0.34^{a}
September	32	27.4 ± 3.18^{a}	5.1 ± 0.35^{a}
October	34	37.4 ± 3.25^{b}	5.6 ± 0.33^{a}
November	34	38.6 ± 3.25^{b}	6.1 ± 0.33^{b}
December	35	36.3 ± 3.25^{b}	6.0 ± 0.27^{b}

^{abc} Values with different superscripts within column are significantly different ($P<0.05$).

Under conventional intensive pig production systems, litter sizes at weaning, is, arguably, the best indicator of sow performance, since it determines the number of pigs that get slaughtered. This is largely because mortality beyond weaning is negligible and is not largely influenced by the mothering ability of the sow, but the level of management. Good nutritional and health management significantly reduces post-weaning mortality. The observation that no significant differences were detected in litter size at three weeks and at weaning across parities in both groups of Mukota sows indicates that parity effects are only important at birth. This suggests that Mukota pigs that survive to three weeks have a higher chance to survive to weaning and post-weaning period. This has been reported in other breeds, such as Landrace and Large White (Mungate *et al*., 1999).

Besides the number of pigs that are weaned, another important variable is the weight of the pigs. Mashatise (2002) suggested that, in smallholder extensive production systems, piglet weight appears to be more important than the size of the litter. In other words, a sow that produces numerous weak piglets can lose them all. As expected, the litter size at weaning per sow affected the TWWT. The higher TWWT and AVWWT in the crossbred genotype than in the Mukota pigs suggest that crossbreeding of Mukota and Large White boars is a possibility to increase weaner productivity (Maburutse, 1992). It is generally expected that litter sizes and body weights would be low during the cold season (Gordon, 1997), since no infra-red lamps were used in this herd. In addition, pigs are expected to expend a lot of heat during the cold season to keep them warm. There is need to determine the heat retention and expenditure in local pigs. It is likely that the Mukota pigs, which are adapted to surviving under extensive tropical production conditions, they do not lose as much heat as temperate breeds as suggested by Scherf (1990). The significant influence of litter size on both TWWT and AVWWT could partly explain the steady and consistent increase in these variables as parity increased.

The observation that parity of sow did not influence the weight of the pigs at three weeks could suggest that mothering ability is not related to the age of the sow. This was despite the fact that litter size at birth was significantly influenced by parity of the sow. This observation could suggest that Mukota sows have a good mothering ability. More work, however, needs to be done to evaluate mothering ability and determine the genetic contribution to this trait. Although the crossbred pigs had higher growth rates from birth up to three weeks than the indigenous Mukota, the rates of growth from three weeks to weaning were similar between these two genotypes. Few, if any, reports are available on the growth rates from three to five weeks in imported pigs in Zimbabwe and other countries in Southern Africa. These findings indicate the enhanced growth performance from three weeks, which tended to surpass their crossbred counterparts. Although the explanation is not clear, there is need to assess the growth patterns in Mukota pigs, using sensitive techniques, such as random regression models to evaluate the genetic determination of such traits. The overall body weight gain up to weaning was not different between the two genotypes could be explained two-fold. First, the Mukota pigs had enhanced performance. Secondly, the crossbred pigs could have lacked adequate amounts of nutrients to meet their fast growth requirements. The diets used for the pigs fibrous and of low energy density. The ADG3TW, therefore, appears to be a trait of economic importance in the genetic evaluation of Mukota pigs. All the pigs in this study were maintained on a fibrous diet, to mimic smallholder production conditions. This might suggest the need for an improved diet for crossbred pigs.

The weight gains before weaning are comparable to those reported for Meishan pigs (Haley *et al*., 1992). The same authors also reported the lack of sex influence on pre-weaning body weight gains. The growth rate before weaning observed in this study revealed that the Mukota have rapid early growth but, perhaps, slow late growth rates. The daily weight gain and AVWWT observed for the Large White × Mukota crossbred pigs compare with Large White, Duroc, Landrace and Hampshire pigs kept under intensive production system in Zimbabwe (Maburutse, 1992; Mungate *et al*., 1999). That growth rate before three weeks of age was lower than growth rate after the third week suggests that these two phases could be treated as different traits in genetic evaluations. These results indicate that the Mukota increase growth rate with age, but the growth rate reaches the plateau early. This could partly explain the ability of piglets to withstand and survive draughts under extensive production systems. Fat content of milk has been observed to reduce piglet mortality. It is, therefore, important to evaluate milk fat content in these breeds and assess its influence on the ability to survive draughts. The performance of the crossbred pigs also compares well with exotic breeds (Haley *et al*., 1992; Maburutse, 1992; Mungate *et al*., 1999). These findings indicate that there is scope in utilising crossbreeding, especially in smallholder commercial production systems to increase weaner productivity.

Mortality of piglets from birth to weaning is a factor of both mothering ability and level of management. The similar management of the pigs in this study means that the differences in piglet mortality are due to genotype and sow effects. There was no influence on TWWT and AVWWT. Such findings suggest that piglet mortalities before weaning were negligible in reducing the weight of the piglets per litter. The similarity in the mortalities between the two pig genotypes could suggest that the crossbred pigs can be used under low-level management conditions in which the purebred Mukota pigs are raised.

The implications of findings in this study are two-fold. The crossbred pigs could be suitable for smallholder or even large-scale commercial pig production, since they have fast growth rates (Chimonyo *et al*., 2001). Fast growth rates are not suitable to communal area production since that translates to higher feed requirements. The Mukota pigs, on the other hand, are ideal for the poor smallholder farmers, as they have low nutrient requirements (Anderson, 2003). Other research areas include determining the quantities and fat content of milk produced by Mukota pigs.

High piglet mortality rates and low growth rates during the cool months of the year could be a cause for concern for smallholder farmers in Southern Africa. These observations agree with Mungate et al. (1999) and emphasise the notion that cold stress tends to be more influential in piglet performance than heat stress, as is normally the case in European and American production systems (Whittemore, 1993).

4.5 Conclusions

Month of the year had no influence on litter size both at three weeks and at weaning in Mukota sows, although no infra-red lamps were installed in the farrowing pens. Parity of sow and month of the year had no influence on the weight traits at three weeks. Crossbred pigs gained body weight faster than Mukota pigs up to three weeks of age. Weaning weights were also higher in the crossbred than Mukota pigs. The weaning weights increased with parity. Body weight gains from three weeks to weaning (five weeks) were similar in both genotypes. Piglet mortality was generally high, and tended to increase with parity.

4.6 References

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Chapter 5: Non-Genetic Factors Affecting Growth Performance and Carcass Traits of Mukota and Large White × Mukota Crossbred Pigs

Abstract

The objective of this study was to determine the influence of genotype, sex and month on post-weaning growth performance and carcass traits of Mukota and Large White × Mukota pigs when fed on maize cob-based diets. All pigs were weighed at two-week intervals to estimate average daily gain. Dressing percentage and carcass lengths were determined. Backfat thickness was measured using a pair of vernier callipers at 50 mm (K5), 75 mm (K7.5) and 100 mm (K10) from the midline. The average body weight gain from weaning up to 12 weeks (ADG1) was 0.42 kg. The average dressing percentage, cold dressed mass, carcass length, K5, K7.5 and K10 were 0.72, 37.5 kg, 581 mm, 11.2 mm, 14.9 mm and 15.9 mm, respectively. Boars had higher body weight gains than gilts ($P<0.05$). The ADG1 for Mukota and crossbred boars were 0.39 and 0.46 kg/day, respectively. Growth rates for crossbred pigs were lower in the cool season than the other seasons ($P<0.05$). Body weights were consistently higher in the crossbred than in the Mukota pigs ($P<0.05$). Mukota pigs showed peak growth between 12 and 16 weeks post-weaning. The dressing percentages were 0.70 and 0.73 for the Mukota and crossbred pigs, respectively. Crossbred pigs had longer ($P<0.05$) carcasses than Mukota (655.5 ± 1.68 versus 507.2 ± 0.92 mm). Although there were no differences in the backfat thickness between males and females of the crossbred pigs, Mukota boars had thicker ($P<0.05$) backfat than the gilts. The mean K7.5 values were 14.6 and 13.0 mm for Mukota and crossbred pigs, respectively.

5.1 Introduction

In Southern Africa, a significant population of indigenous pigs is found in smallholder communal areas of Mozambique, South Africa, Zambia and Zimbabwe (Lekule *et al*., 1990). Recent studies provide evidence that Mukota pigs are hardy (Holness, 1991; Zanga *et al*., 2003) and better able to utilise agricultural by-products, such as maize cobs than imported pigs (Kanengoni *et al*., 2002; Ndindana *et al.,* 2002). Under smallholder farming conditions, feed resources are scarce and, if available, prices are prohibitive. Use of local and readily available feed resources promotes the sustainability of smallholder pig production and increases the efficiency of resource utilisation (Anderson, 2003).

Utilisation of indigenous and crossbred pigs in commercial production systems requires documentation of the factors that influence their performance. To take advantage of the exotic genes, smallholder farmers usually practise crossbreeding (Scherf, 1990). Environmental factors that influence their performance are not known. However, Chimonyo *et al*. (2001) and Kanengoni *et al*. (2004) observed that Large White × Mukota crossbred pigs grow faster than indigenous Mukota pigs and are equally efficient in utilising fibrous diets than purebred Large White pigs.

Besides reproductivity, traits of economic importance in pigs are growth performance and carcass characteristics. Quantifying the contribution of individual factors assists in pig management and reducing production costs, for example related to feed consumption. Carcass traits, such as dressed weight, length and conformation of the carcasses are direct determinants of carcass grades and, thereby, revenue. In Zimbabwe, Mukota pigs tend to be shunned because their short carcasses cannot easily be prepared into specialised meat cuts (Dzama, personal communication). Identifying factors that influence such traits is thus crucial in improving smallholder pig agriculture. The objective of this study was, therefore, to assess the influence of month, sex and genotype on post-weaning growth performance and carcass traits of Mukota and Large White × Mukota pigs when fed on a fibrous diet.

5.2 Materials and Methods

5.2.1 Study site

The study site was described in Section 3.2.1.

5.2.2 Animals and general management

The management procedures of the animals were described in Sections 3.2.2 and 3.2.3. Diets for growing pigs were formulated to contain 153.5 g CP/kg and 11.75 MJ ME/kg and contained 150 g maize cob meal/kg.

5.2.3 Data and traits analysed

Data were collected between January 1998 and August 2003 and comprised of 2467 and 640 individual pig records of each of Mukota and Large White × Mukota crossbred pigs, respectively. Pigs were slaughtered between 20 to 35 weeks of age. Changes in body weights were used to estimate the average daily gain. Changes in body weights and average daily gain (ADG) from weaning to slaughter were calculated using two-weekly body weight measurements. Growth phases were split into two, before and after 12 weeks of age. The ADG before and after the 12-week mark were designated ADG1 and ADG2, respectively.

Dressing percentage (DP) was estimated by dividing the difference between the body weight at slaughter and the hot dressed weight by the body weight at slaughter. Carcass length (CL) was measured from the anterior edge of the first rib to the pubic bone using a measuring tape. The carcasses were left to chill overnight at 4°C before being weighed 24 hours after slaughter to determine cold dressed mass (CDM). Each carcass was cut cross-sectionally at the level of the last rib up to and across the spinal cord to measure the thickness of backfat. Backfat thickness was measured using a pair of vernier callipers at 50 mm (K5), 75 mm (K7.5) and 100 mm (K10) from the midline.

5.2.4 Statistical analyses

Changes in body weight were analysed using the PROC MIXED procedure with repeated measures analysis (SAS, 2000). For each phase, the model used was:

$Y_{ijklm} = \mu + G_i + M_j + W_k + P_l + (G \times M)_{ij} + (G \times W)_{ik} + (G \times M \times W)_{ijk} + \beta_1(WWT) + A_m + E_{ijklm}$;

where:

Y_{ijklm} = fortnightly body weights

μ = overall mean response

G_i = fixed effect of the i^{th} genotype

M_j = fixed effect of the j^{th} sex of the pig

W_k = repeated effect of week

P_m = fixed effect of parity of sow

$(G \times M)_{ij}$ = genotype × sex interaction

$(G \times W)_{ik}$ = genotype × week interaction

$(G \times M \times W)_{ijk}$ = genotype × sex × week interaction

β_1 = partial linear regression coefficient of the dependent variable on weaning weight

A_m = random effect of pig

E_{ijklm} = residual error

The generalised linear models procedure (SAS, 2000) was used to evaluate the influence of breed of sire, sex, month of birth, parity of sow and all the first-order interactions on the overall ADG, ADG1 and ADG2. The weight at weaning for each pig was incorporated into the linear model as a covariate. A similar model was used for DP, CDM, CL, K5, K7.5 and K10. For CDM and backfat thickness, the weight at slaughter was used as a covariate. Pair-wise comparisons were performed using the Tukey's W-procedure (SAS, 2000).

5.3 Results

5.3.1 Summary statistics and levels of significance

The summary statistics for the traits analysed are presented in Table 5.1. Of the backfat measurements, K10 had the widest range (16 mm). The levels of significance of the fixed factors are presented in Table 5.2. Parity of the sow did not significantly influence (P>0.05) any of the traits measured in this study.

Table 5.1: Summary statistics for overall ADG, gain from weaning to 12 weeks (ADG1), gain from 12 weeks to slaughter (ADG2), cold dressed mass (CDM), dressing percentage (DP), carcass length (CL) and backfat thickness at K5, K7.5 and K10

Trait	N	Mean	SD	Minimum	Maximum
Overall ADG (kg)	3107	0.38	0.10	0.2	0.6
ADG1 (kg)	3107	0.42	0.09	0.2	0.6
ADG2 (kg)	3107	0.34	0.16	0.2	0.6
DP (%)	3107	72	7.01	70.0	80.1
CDM (kg)	3107	37.50	7.86	11.5	51.4
CL (mm)	3107	581.41	51.28	468.0	793.0
K5 (mm)	3107	11.23	1.77	6.0	13.0
K7.5 (mm)	3107	14.91	3.90	9.0	17.0
K10 (mm)	3107	15.92	5.79	8.0	24.0

N: sample size; SD: standard deviation.

Table 5.2: Significant levels of the factors and covariates included in the analyses

	Main effects			Interactions			Covariates	
Trait	G	M	S	G × S	G × M	G × S × M	β_1	β_2
Overall ADG (kg)	**		*	*	**	*	*	
ADG1 (kg)	*		*	*	**	*	*	
ADG2 (kg)	**	**		*	**	*		
DP (%)	*	*						
CDM (kg)	**	**		*	*	*		*
CL (mm)	***			*				
K5 (mm)	*		*	*	**			
K7.5 (mm)	**		*	*	*			
K10 (mm)	*				*			*

Abbreviations: ADG: average daily gain, ADG1: ADG before 12 weeks of age, ADG2: ADG after 12 weeks of age, DP: dressing percentage, CDM: cold dressed mass, CL: carcass length, K5: backfat at 50 mm from the midline along the last rib, K7.5: backfat thickness at 75 mm, K10: backfat thickness at 100 mm.

G: breed of sire, M: sex of pig, S: month of slaughter, β_1: weight at weaning, β_2: weight at slaughter.

*P<0.05, **P<0.01 ***P<0.001

5.3.2 Changes in body weights and average daily gain

Changes in body weight were influenced by the sex of the pig, genotype and season of birth ($P<0.05$). Boars had higher body weight gains ($P<0.05$) than gilts. Changes in body weight in the Mukota and crossbred pigs are depicted in Figure 5.1. The Large White × Mukota crossbred pigs had higher body weights than Mukota pigs. The body weights were consistently higher in the crossbred than in the Mukota pigs. Mukota pigs tended to show the peak growth between 12 and 16 weeks post-weaning. The majority of the Mukota pigs in this study were slaughtered at this age. There was a significant genotype × month interaction ($P<0.05$) on body weight changes. The weaning weight, which was incorporated as a covariate, also influenced changes in body weight ($P<0.05$). Parity of sow did not influence ($P>0.05$) body weights at slaughter. Figure 5.2 shows the changes in average daily gain in Mukota and crossbred pigs. There were no significant differences ($P>0.05$) in the overall ADG from week 12 to 30 post-weaning. As shown in Table 5.3, there was a significant interaction ($P<0.05$) between breed of sire and sex of pig on both ADG1 and ADG2. Within genotype, ADG1 for males was higher ($P<0.05$) than for females. No differences ($P<0.05$), however, were detected in the ADG2 for the Mukota pigs. Table 5.4 shows the influence of month and genotype on ADG1 and ADG2. Month affected ($P<0.05$) ADG1, but not ADG2 ($P>0.05$). Low gains were obtained from June to August, particularly for the Mukota.

Figure 5.1: Changes in body weight of Mukota and Large White × Mukota crossbred pigs

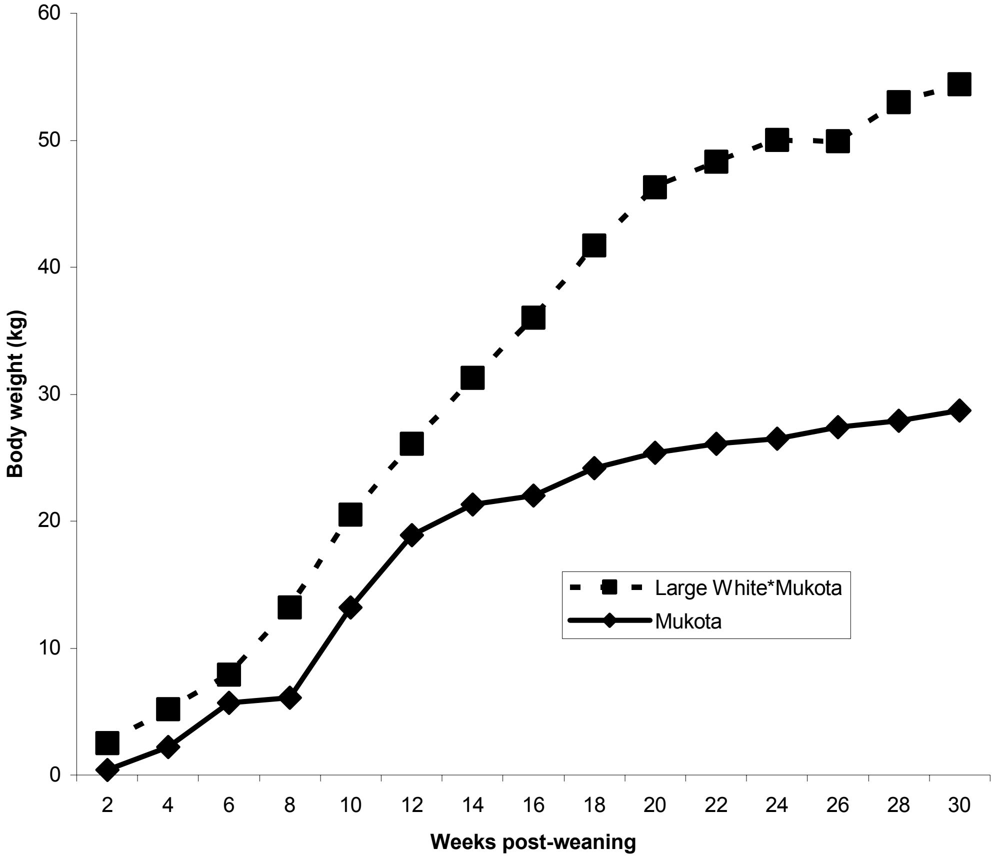

Figure 5.2: Changes in average daily gain for Mukota and Large White × Mukota crossbred pigs

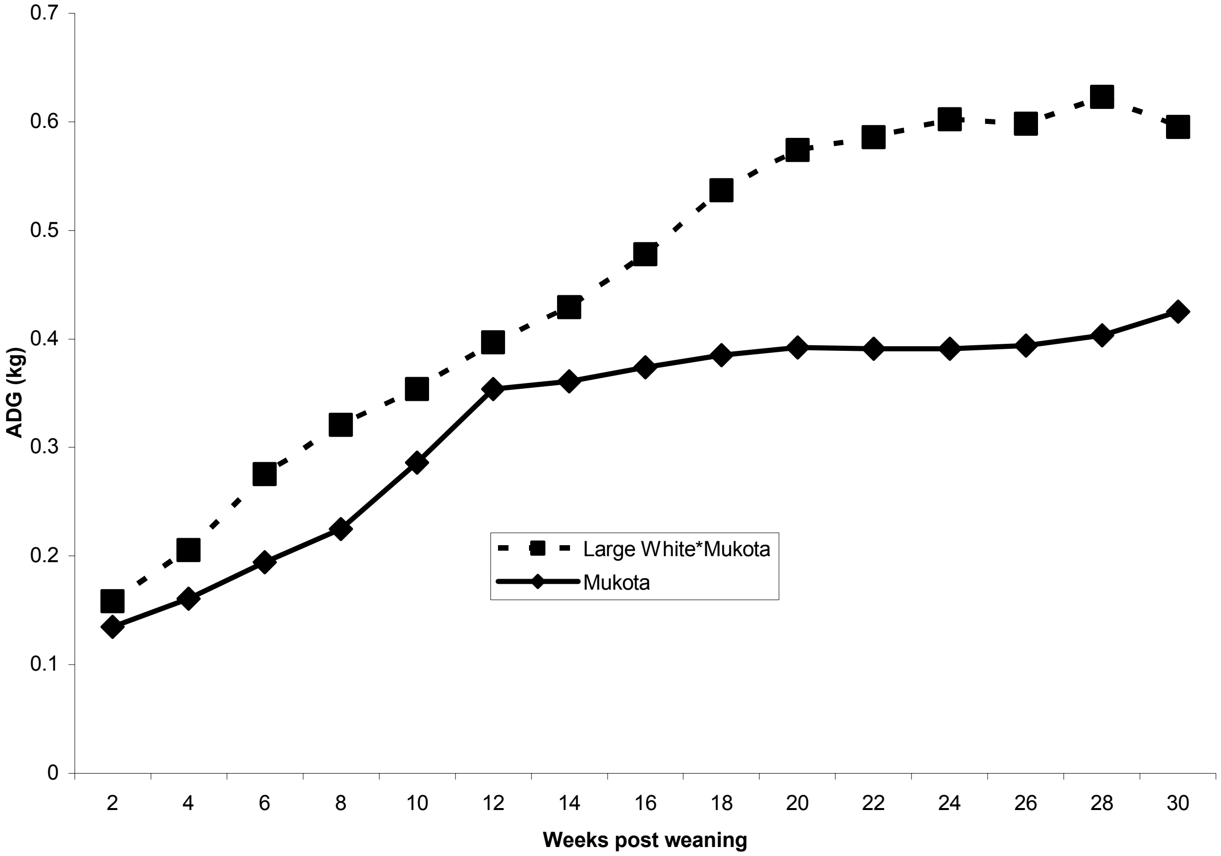

Table 5.3: Interaction between breed of sire and sex on average daily gain from weaning to 12 weeks of age (ADG1) and 12 weeks to slaughter (ADG2)

Breed of sire	Sex	N	ADG1 (kg/day)	ADG2 (kg/day)
Mukota	Male	1237	0.39 ± 0.013^{b}	0.20 ± 0.012^{a}
Mukota	Female	1230	0.34 ± 0.012^{a}	0.19 ± 0.012^{a}
Large White	Male	340	0.52 ± 0.012^{d}	0.52 ± 0.021^{c}
Large White	Female	300	0.46 ± 0.013^{c}	0.43 ± 0.024^{b}

^{abcd} Values with different superscripts within column are significantly different ($P<0.05$).

Table 5.4: Least square means (± standard errors) for average daily gain from weaning to 12 weeks of age (ADG1) and 12 weeks to slaughter (ADG2) in pigs sired to Mukota and Large White boars across months

	ADG1 (kg/day)				ADG2 (kg/day)			
Month	N	Mukota	N	Crossbreds	N	Mukota	N	Crossbreds
January	205	0.37^{b}	55	0.51^{b}	205	0.20	55	0.56
February	210	0.34^{ab}	53	0.42^{a}	210	0.16	53	0.58
March	195	0.38^{b}	52	0.45^{ab}	195	0.21	52	0.61
April	210	0.39^{b}	55	0.59^{c}	210	0.20	55	0.57
May	215	0.40^{bc}	60	0.53^{bc}	215	0.18	60	0.56
June	201	0.31^{a}	61	0.41^{a}	201	0.20	61	0.57
July	206	0.30^{a}	45	0.45^{ab}	206	0.21	45	0.55
August	196	0.34^{ab}	42	0.44^{a}	196	0.19	42	0.60
September	214	0.38^{b}	39	0.57^{c}	214	0.16	39	0.58
October	208	0.41^{c}	58	0.48^{b}	208	0.21	58	0.59
November	188	0.38^{b}	52	0.59^{c}	188	0.19	52	0.62
December	219	0.44^{d}	68	0.49^{b}	219	0.18	68	0.58

^{abcd}Values with different superscripts within column are significantly different ($P<0.05$). Standard errors for ADG1 ranged from 0.010 to 0.015. They ranged from 0.12 to 0.024 for ADG2.

5.3.3 Carcass performance

Crossbred pigs had a higher dressing percentage than Mukota pigs ($P<0.05$) (73 versus 70 %, respectively). The DP was not influenced ($P>0.05$) by parity, month or sex of the pig. Both the genotype of the pig and age at slaughter (used as a covariate) significantly ($P<0.05$) influenced CDM. The CDM was significantly higher ($P<0.05$) in the crossbred than Mukota pigs. Carcass lengths for the Mukota and crossbred pigs were 507.2 ± 0.92 and 655.5 ± 1.68 mm, respectively. Table 5.5 presents the least square mean backfat measurements in Mukota and crossbred pigs. There were significant ($P<0.05$) genotype differences on the three backfat measurements. Although there were no differences ($P>0.05$) in the backfat thickness between males and females of the crossbred pigs, Mukota boars had thicker backfat ($P<0.05$) than the gilts. Month of slaughter influenced ($P<0.05$) both K5 and K7.5, but not K10 ($P>0.05$) backfat thickness (Table 5.6). The standard errors for K10 tended to be higher than for K5 and K7.5.

5.4 Discussion

The study was designed to assess the performance and carcass traits of growing Mukota and Large White × Mukota pigs fed on diets based on maize cobs. The performance of the pigs determines the ability of the pigs to utilize fibrous diets, which are found in abundance in smallholder farming areas. The observation that boars had higher body weight gains, especially for the Mukota, could indicate the influence of male sex hormones, such as testosterone, in enhancing growth performance of males. These findings suggest that most of the pigs were slaughtered when they had attained puberty. There is, therefore, need to evaluate the age and body weight at which puberty is attained.

Table 5.5: Backfat thickness at the K5, K7.5 and K10 positions in male and female Mukota and Large White × Mukota crossbred pigs

			Backfat thickness (mm)		
Breed of sire	Sex	N	K5	K7.5	K10
Mukota	Male	1237	12.1 ± 0.03^d	14.9 ± 0.04^d	15.4 ± 0.18^a
Mukota	Female	1230	11.4 ± 0.03^c	14.3 ± 0.04^c	15.2 ± 0.16^a
Large White	Male	340	10.6 ± 0.06^a	12.8 ± 0.07^a	17.2 ± 0.15^b
Large White	Female	300	10.8 ± 0.06^b	13.2 ± 0.07^b	15.7 ± 0.18^a

^{abcd} Values with different superscripts within column are significantly different ($P<0.05$).

Table 5.6: Effect of month on backfat thickness (K5, K7.5 and K10) across the two genotypes

Month	N	K5	K7.5	K10
January	260	10.2 ± 0.03^{b}	14.9 ± 0.04^{c}	17.2 ± 0.19
February	263	10.4 ± 0.03^{c}	13.3 ± 0.05^{a}	16.7 ± 0.12
March	247	10.6 ± 0.06^{d}	13.8 ± 0.11^{b}	17.4 ± 0.12
April	265	10.7 ± 0.06^{d}	13.2 ± 0.07^{a}	19.7 ± 0.23
May	275	10.1 ± 0.03^{b}	13.9 ± 0.04^{b}	17.2 ± 0.38
June	262	10.4 ± 0.03^{b}	13.3 ± 0.04^{a}	17.2 ± 0.29
July	251	10.6 ± 0.06^{b}	13.8 ± 0.07^{b}	17.4 ± 0.23
August	238	9.9 ± 0.06^{a}	13.2 ± 0.07^{a}	16.9 ± 0.18
September	253	10.1 ± 0.03^{b}	13.9 ± 0.06^{bc}	16.4 ± 0.18
October	266	10.4 ± 0.03^{c}	13.3 ± 0.08^{a}	17.2 ± 0.21
November	240	10.6 ± 0.06^{d}	13.8 ± 0.07^{b}	18.4 ± 0.29
December	287	10.8 ± 0.06^{d}	14.2 ± 0.07^{c}	19.1 ± 0.21

^{abcd}Values with different superscripts within column are significantly different ($P<0.05$).

Values are given as least square means ± standard errors.

Earlier reports (e.g. Holness, 1991) indicated that Mukota pigs could attain puberty from as early as three months of age. By monitoring eight gilts, Mashatise (2002) reported that Mukota pigs started showing signs of oestrus at 157 days of age. In that study, however, the gilts had no exposure to boars, which have been shown to reduce the age at which pigs start to cycle (Whittemore, 1993).

The low growth rates of the crossbred pigs in the cool season could be due to loss of substantial amounts of feed energy to keep the pigs warm. This suggests that Mukota pigs have lower maintenance requirements than their crossbred counterparts. The finding that parity of sow had no influence on body weights at slaughter indicates that body weights are largely a factor of the feeding and health management of the weaned pigs and not necessarily the management of the sows. Maternal effects are, thus important only during the early stages of life.

The consistently higher body weights in the crossbred than Mukota pigs suggest the probable effect of heterosis from the Large White and Mukota parents. In a previous growth performance trial (Kanengoni *et al*., 2004) crossbred pigs showed higher growth rates than pure Large White pigs. Based on the previous findings, Large White pigs are inappropriate to use under smallholder production systems that utilises fibrous diets. For that reason, pure Large White pigs were not used in this study. The observation that Mukota pigs tended to mature earlier than the crossbred pigs indicates that ages at slaughter should be breed-specific. Keeping Mukota pigs for longer periods than is optimum reduces efficiency of feed conversion since most of the dietary nutrients are converted into fat (English *et al*., 1988; Whittemore, 1993). Feed consumption levels were not reported in this study since the pigs were fed in groups. Previous reports (Kanengoni *et al*., 2002), however, suggest that no differences in feed intake exist between the two breeds when fed on a similar diet and the intake expressed relative to the weight of the animal. The crossbred pigs are likely to be more efficient in converting dietary nutrients than the indigenous genotypes. Crossbred pigs, therefore, seem likely to be the appropriate breed to produce in commercialised smallholder pig production. More work, however, needs to be done on evaluating the performance of the second filial generation crossbreds and their reciprocal crosses.

Dressing percentage was computed as the difference in weight of the live weight before slaughter and after removal of intestines and internal organs. The trotters and the head were measured as part of the carcass. The finding that Mukota pigs had a lower dressing percentage than their crossbred counterparts could be explained by the large internal organs in the Mukota pigs. Mukota pigs have been shown to have a larger colon and caecum than exotic Large White pigs (Dzikiti and Marowa, 1997). These large segments have been suggested to explain the enhanced ability of the indigenous pigs to digest and utilize fibrous diets (Kanengoni *et al*., 2002).

The larger carcasses produced by crossbred pigs than Mukota indicates that the crosses produce carcasses that can easily be cut into cuts, as is done with the Large White. Carcasses from Mukota pigs, which are small and compact, are difficult to process into cuts. This is because carcasses from crossbred pigs, like those from the exotic breeds, are longer than Mukota pigs. In Zimbabwe, the proportion of fat in the carcass is estimated by measuring backfat thickness 75 mm (K7.5) from the midline along the last rib. This position was shown to be the best indicator of the amount of muscle in the carcass. It is not yet clear whether this position is a good indicator across all breeds. It is, however, likely that in small-framed genotypes, such as Mukota, the K7.5 position is inappropriate. The main pork processor in Zimbabwe, COLCOM, pays farmers based on percentage lean. There is, therefore, need to determine the site of measurement of backfat that reliably estimates the lean content of a carcass.

There is need to estimate the muscle weight and relate with each backfat measurement to identify the most appropriate position. The position of backfat measurement is the one that is used in determining the quality and monetary value of each carcass. The observation that at position K5 and K7.5, Mukota pigs had thicker fat than the crossbreds could indicate the high propensity to deposit body fat in the Mukota pigs. Fat deposition is often thought to be an adaptation to adversity in which they deposit fat when they have more than adequate nutrient intake. They use the body nutrients when they are deprived of food. At the K10 position, the Mukota pigs show thinner backfat than the crossbreds, which is related to their small body structure. The lack of differences in the backfat thickness between males and females of the crossbred pigs is expected (Haley *et al.*, 1992). Pigs are usually slaughtered before they reach puberty. In the Mukota pigs, however, the differences in backfat thickness between boars and gilts might suggest that these pigs were slaughtered well after they had attained puberty.

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