Climate change adaptation and economic valuation of local pig genetic resources in communal production systems of South Africa

By

JAMES MADZIMURE

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Department of Livestock and Pasture Science

School of Agriculture and Agribusiness

Faculty of Science and Agriculture

University of Fort Hare
Together in Excellence

Alice, Republic of South Africa

Promoter: Prof. M. Chimonyo

Co-promoter: Prof. K. Dzama

Associate-promoter: Dr. K.K. Zander

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Declaration

I, James Madzimure, declare that this dissertation has not been submitted to any university and that it is my original work conducted under the supervision of Prof. M. Chimonyo, Prof. K. Dzama and Dr. K.K. Zander. All assistance towards the production of this work and all the references contained herein have been duly credited.

………………………………………….. …………………………………….

James Madzimure **Date**

Approved as to style and content by:

……………………………………….. ……………………………….

Prof. M. Chimonyo **Prof. K. Dzama**

(Promoter) (Co-promoter)

………………………………………..

Dr. K.K. Zander

(Associate promoter)

November 2011

List of abbreviations

ABP	Ashanti Black Pig
ADFI	Average daily feed intake
ADG	Average daily gain
AnGR	Animal genetic resources
ARC	Agricultural Research Council
ASF	African swine fever
Bpm	Breaths/beats per minute
BR	Breathing rate
BV	Bequest values
CBMAnGR	Community-based management of animal genetic resources
CE	Choice experiment
CI	Confidence interval
CP	Crude protein
CR	Choices ranking
CSF	Classical swine fever
CV	Contingent valuation
DM	Dry matter
DNA	Deoxyribonucleic acid
DUV	Direct use value
FACT	Farm Animal Conservation Trust
FAO	Food and Agriculture Organisation

FCE	Feed conversion efficiency
FCR	Feed conversion ratio
FRFRB	Free ranging feed resource base
GLM	Generalised linear model
HR	Heart rate
IK	Indigenous knowledge
IUV	Indirect use values
LW	Large White
ME	Metabolisable energy
MJ	Megajoules
MNL	Multinomial logit
MO	Market-oriented production system
NAFU	National African Farmers Union
NOAA	National Oceanic and Atmospheric Administration
OV	Option values
PDIFF	Probability difference
RP	Revealed preference
RT	Rectal temperature
RUM	Random utility theory
SADC	Southern African Development Community
SAPA	South African Press Association
SAS	Statistical analysis system
SO	Subsistence-oriented production system

SP	Stated preference
SST	Skin surface temperature
TEV	Total economic value
THI	Temperature humidity index
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USD	United States of America dollars
VFI	Voluntary feed intake
WMO	World Meteorological Organization
WOAH	World Organisation on Animal Health
WTA	Willingness-to-accept
WTP	Willingness-to-pay
XV	Existence values

Abstract

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The broad objective of the study was to determine the economic value of local pigs in market- and subsistence-oriented production systems in communal areas of Southern Africa. Data were collected from 288 households to investigate farmer perceptions, effects on pig production and handling of disease outbreaks such as classical swine fever (CSF) in market- and subsistence-oriented production systems. The utilisation of local pigs in these market- and subsistence-oriented production systems in improving people's welfare was evaluated. Climate change was identified by farmers in these production systems as a major constraint to pig production hence an experiment was carried out in the hottest season to determine diurnal heat-related physiological and behavioural responses in Large White (LW) and South African local pigs. The same genotypes were used to determine effects of diurnal heat-related stress on their growth performance. Choice experiment was done to determine farmer preferences for local pig traits and implicit prices for these traits in CSF-affected and unaffected areas that were under subsistence- and market-oriented production systems. In this experiment, the importance of heat tolerance was assessed relative to other productive and climate change adaptation traits.

Significantly more pigs were culled in the CSF-affected areas that were market-oriented (8.0 ± 1.76) than subsistence-oriented (4.1 ± 1.00) production system. The risk of parasites and disease challenges was high in subsistence-oriented production system and coastal areas. In both production systems, CSF was perceived as destructive since the culling of pigs affected pork availability and income generation. The high risk of disease outbreaks and threat of climate change caused farmers in subsistence-oriented production system to select local pigs for their adaptive traits while those in the market-oriented production system focused on productive imported pigs. Farmers (83 %) indicated that they wanted pig genotypes that were adapted to climate change effects such as hot conditions. Local pigs were found to have superior heat tolerance over LW pigs ($P < 0.05$) in terms of lower heart rate and skin surface temperature. Frequency per day and duration for behavioural heat loss activities such as wallowing, sleeping in a prostrate posture and sprawling in slurry were also lower ($P < 0.05$) for local than LW pigs. The superiority of heat tolerance of local over LW pigs was further confirmed by their uncompromised growth performance under high diurnal temperatures. The Pearson's product moment correlation coefficient between temperature and feed conversion ratio for LW pigs was strongly positive ($r = 0.50$; $P < 0.001$) unlike the weak and positive correlation for local pigs ($r = 0.20$; $P < 0.05$). There was a quadratic relationship between temperature and average daily gain (ADG) for both pig genotypes. The regression coefficients for ADG were higher ($P < 0.001$) for LW than local pigs. It was concluded that at high ambient temperatures, performance of local pigs was less compromised than for LW pigs. Although local pigs were found to be heat tolerant, results of choice experiment showed that this trait was not selected for relative to other traits. Keeping pigs that required bought-in feeds, fell sick often and produced low pork quality (eating quality based on farmer perceptions) negatively affected farmers' livelihoods more in

subsistence- than market-oriented production system. Farmers in market-oriented production system derived more benefit from productive traits such as heavier slaughter weights and large litter size than subsistence-oriented farmers. Under the subsistence-oriented production system, farmers in CSF-affected areas placed high prices on adaptive traits than the unaffected areas. Subsistence-oriented farmers who were affected by CSF wanted a total compensation price of R10 944.00 (USD1563.43) for keeping a pig genotype with unfavourable traits when compared to R4235.00 (USD605.00) for their CSF-unaffected counterparts. Implicit prices for traits could not be determined for market-oriented production system. It was concluded that farmers in CSF-affected areas placed high economic values on pig traits than farmers from the CSF-unaffected areas. The findings suggest that adapted local pigs can be promoted in subsistence-oriented production systems while productive imported pigs and their crosses with local pigs can be kept in market-oriented production systems.

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CHAPTER 1: Introduction

1.1 Background

Livestock is a major source of livelihood for many communities worldwide, particularly the resource-limited smallholder farmers (Wanzala *et al.*, 2005). According to FAO (1999), domestic animals supply over 30 % of total human requirements for food and agriculture. The socio-economic roles of livestock include savings, insurance, cyclical buffering, accumulation and socio-cultural roles (Wilson, 1995; Anderson, 2003; Halimani *et al*., 2010). These diverse roles entail that there is need for conservation of livestock diversity to support sustainable agricultural development (Drucker and Anderson, 2004). Currently, an estimated 16 % of uniquely adapted genotypes domesticated in a wide range of environments have been lost over the last century (Hall and Ruane, 1993). Approximately 70 % of livestock genotypes today are found in developing countries where the risk of loss is highest (Rege and Gibson, 2003). The major factors that threaten local animal genetic resources (AnGR) in Southern Africa include climate change, globalisation, disease outbreaks, indicriminate crossbreeding, replacement of local genotypes by imported genotypes; urbanisation; drought and political instability (Rege and Gibson, 2003; Philipsson and Okeyo, 2006).

The expected increase in ambient temperatures in most parts of Southern Africa, due to climate change, is a major challenge for pigs. Pigs have poor thermoregulatory mechanisms (Huynh, 2005; Renaudeau *et al*., 2008; Zumbach *et al*., 2008). Local pig genotypes that are thought to be heat tolerant are likely to survive these extreme temperatures (Nengomasha, 1997). These local pigs are adapted to tropical environments and include the Mukota pig of Zimbabwe and the

Windsnyer predominantly found in South Africa and Mozambique. Molecular genetic characterisation has established that all the local pigs in Southern Africa are similar (Halimani *et al*., 2011), and are likely to have similar traits. The mechanisms behind their heat tolerance are, however, poorly understood. There is no information on the performance of Southern African pig genotypes under diurnal heat-related stress that could increase their value or reduce costs of production. An understanding of heat tolerance mechanisms can assist in designing appropriate management systems and to indicate adverse heat stress levels. The general rise in global temperatures will have compound effects on pig production in Southern Africa (Scholtz, 2009). For example, climate change could cause water shortages (Gregory, 2010). During hot conditions, pigs would like to drink or wallow in water to cool down yet this important resource will be scarce.

High disease incidences are also associated with increasing temperatures where most farmers in communal production systems (rural areas where natural resources such as land/or rangelands are communally owned) cannot afford to buy veterinary medicines. In the last decade, there were outbreaks of classical swine fever (CSF) in South Africa, hog cholera in Malawi and parts of Mozambique although it is not clear whether it was associated with climate change effects [World Organisation on Animal Health (WOAH), 2005; National African Farmers Union (NAFU), 2007; National Department of Agriculture, 2009]. The outbreak of CSF and the major devastations it caused calls for a need to understand farmer perceptions on pig diseases in communal production systems. Use of disease resistant local pig genotypes is one strategy to counter the effects of climate change in these vulnerable communal production systems. Further investigations are, however, required to assess suitability of these pig genotypes for farmers pursuing different production goals in communal production systems. Climate change could also be associated with increased feed shortages (Gregory, 2010) and encroachment of fast growing fibrous plants. Local pigs that have foraging ability may become increasingly important under the communal production systems. Utilisation of fibrous plants might cut down costs of production for the resource-limited farmers. Local pig genotypes that are adapted to these climate change-induced harsh conditions are more likely to continue to contribute to resource-limited farmers' livelihoods.

Despite the adaptive traits of local pig genotypes, they are threatened by replacement and uncontrolled crossbreeding with imported pigs (Chimonyo *et al*., 2005; 2010). Policy makers in Southern Africa promote imported pigs based on their productive traits under commercial conditions (Halimani *et al*., 2010; Pilling, 2010). This capital intensive production system is beyond the scope of existing human and capital resources available to subsistence economies in communal production systems of Southern Africa. Local pigs are discriminated against in conventional food producing systems and their true economic values for farmers are grossly underestimated (Devendra, 2005). Sustainable breeding and on-farm conservation programmes for local pig genetic resources can help farmers to adapt to future environmental shocks. For example, local pig genetic resources are useful in the development of appropriate genotypes as the environment; animal production trends, market and human needs change (Philipsson and Okeyo, 2006). To invest into conservation programmes, however, requires the economic valuation of pigs' socio-cultural functions, adaptive and productive traits to establish their total economic value (TEV) as has been done with other livestock species (Scarpa *et al*., 2003; Zander, 2011). The non-conventional utilities of local pigs such as manure, assets, security, farm integration and socio-cultural relevance can be as important, or even of more value to the resource-limited communal farmers than commercial farmers (Simianer, 2005; FAO, 2007; Ahtiainen and Pouta, 2011). Those pig genotypes with maximum benefit to communal farmers and highest genetic diversity should be prioritised for conservation investment.

In communal production systems, farmers have multiple and complex production objectives that are driven by their immediate subsistence needs rather than demand for a market as was reported in Vietnam (Roessler *et al*., 2008). While monetary returns are the major goal in high-input enterprises, biological survival and established cultural traditions define the essential values of the resource-limited. Valuation of pig genotypes, based on market driven traits, disadvantages the local pigs which have many non-use values and option values (against diseases or climate change) to the buyer (FAO, 2007). Option values refer to future uses of a genetic resource such as breeding and development of new traits. Non-use values cover bequest, altruistic (value placed on conserving genetic resources for future generations and for others in the current generation, respectively) (e.g. Pearce and Moran, 1994; Bateman *et al*., 2003) and existence values of pigs (Drucker and Anderson, 2004). Farmers can value the existence of local pig genetic resources without necessarily using them or they can be preserved for current and future generations. The difference between the market value of the local pig genotype and its TEV to its owner might be large (Roessler *et al*., 2008). Little is known about the TEV for local pigs of Southern Africa since they are not traded on the conventional market and no empirical studies have attempted to estimate it directly. To our knowledge, the monetary values of socio-cultural functions, adaptive and productive traits of local pigs under tropical environment of Southern Africa have never been established.

The role of non-market valuation tools such as choice experiments as decision aids, is paramount (Lancaster, 1966; Louviere *et al*., 2000), particularly because of the absence of efficiently working markets for many of the functions that local pigs perform (Scarpa *et al*., 2003; Liljenstolpe, 2008; Roessler *et al*., 2008). A choice experiment study carried out in Mexico showed that local pig genotypes were preferred for adaptive traits such as foraging ability, tolerance to harsh ambient conditions, digestive capacity for fibrous diets and good mothering ability (Scarpa *et al*., 2003). Research should establish the traits of economic importance for pig producers in communal production systems of Southern Africa and estimate monetary values for these traits.

1.2 Justification

The outbreak of CSF and other diseases is a threat to the erosion of local pig genetic resources of Southern Africa. To promote conservation of these local pigs, their economic values should be determined. The extent of the contributions of local pigs to resource-limited farmers is poorly understood. Lack of information on the economic values for local pig genetic resources contributes to their under-valuation and erosion of biodiversity as they are replaced by imported genotypes. To generate TEV, information on the adaptive and productive traits for local pigs of Southern Africa is required. Economic valuation is the basis for making informed decisions about costs and benefits of conservation. Thus, policy makers can choose between allocation of resources between conservation and alternative uses. For example, incentive structures can be established for the conservation of genetic resources that are not favoured by market systems but could be ideal for sustainable development of communal production systems. Candidates for conservation could be those pig genotypes that are adapted to climate change effects in terms of drought, heat and disease tolerance. Involving farmers in decision-making about their resources also assists in developing sustainable breeding and conservation programmes for local pig genetic resources. Knowledge of the TEV of local pigs help farmers to avoid the simple upgrading (gene flow) methods that have been promoted and utilised in Southern Africa to replace local pig populations with superior genotypes which may not thrive under communal production systems. The findings of the study are likely to help policy-makers and farmers to decide whether to include local pig genotypes in cross-breeding programmes with imported genotypes for complementarity and heterosis.

1.3 Objectives

The broad objective of the study was to determine the total economic value of local pigs in communal production systems of Southern Africa. The specific objectives were to:

1. Investigate farmer perceptions, effects on pig production and handling of disease outbreaks in communal production systems of South Africa;
2. Evaluate the utilisation of local pigs in subsistence-oriented and market-oriented communal production systems of South Africa;
3. Determine diurnal heat-related physiological and behavioural responses in Large White (LW) and South African local pigs;
4. Assess growth performance of LW and South African local pigs under diurnal-related heat stress; and
5. Determine economic values for productive and adaptation traits to climate change effects for South African local pigs.

1.4 Hypotheses

The null hypotheses tested were that:

1. There were no differences in farmer perceptions, effects on pig production and handling of disease outbreaks in market- and subsistence-oriented communal production systems of South Africa;
2. There were no differences in the utilisation of local pigs in subsistence- and market-oriented communal production systems of South Africa;
3. There were no differences in diurnal heat-related physiological and behavioural responses in LW and South African local gilts;
4. There were no differences in growth performance of LW and South African local gilts under diurnal-related heat stress; and
5. Economic values for productive and adaptive traits to climate change effects for South African local pigs in market- and subsistence-oriented communal production systems were not different.

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CHAPTER 2: Review of Literature

2.1 Introduction

Utilisation of local pig genotypes in communal production systems has the potential to increase food security, reduce poverty and improve livelihoods of resource-limited farmers. Diseases outbreaks such as classical swine fever (CSF) in South Africa and African swine fever (ASF) in Malawi and Mozambique (Halimani *et al*., 2010) have, however, caused havoc in Southern African Development Community (SADC) countries. In addition to diseases, the continued existence of local pig genotypes in communal production systems has been threatened by indiscriminate crossbreeding or replacement by imported pigs. Restocking communal areas with adapted pig genotypes that are better able to survive such major disease outbreaks in Southern African countries is, therefore, important.

The greatest dangers of climate change relates to its adverse impact on feed availability, disease distribution and pig welfare (Finocchiaro *et al*., 2005; FAO, 2008; Hoffmann, 2010). The risk of losses of livelihoods due to climate change is likely to be high in sub-Saharan Africa because of the limited ability of farmers to adapt (Hoffmann, 2010). Species and individuals that are responsive to change are likely to survive (Gregory, 2010). Maintaining pig genetic diversity allows farmers to select genotypes in response to the prevailing circumstances, be it climate change, new or resurgent disease threats or changing market conditions (Hoffmann, 2010). Successful conservation of local threatened pig genetic resources, however, depends on understanding existing pig production systems, identification of farmers' breeding objectives, constraints and management practices, and determination of the value placed on the local pigs.

This review discusses communal pig production systems, functions and purposes of pigs in communal production systems, characteristics of local pigs, threats to local pigs and the need for conservation, identification of traits of economic importance in local pigs, and climate change and its effect on pig production and methods for economic valuation of pigs.

2.2 Communal pig production systems in Southern Africa

In communal production systems of Southern Africa, local pigs are a source of livelihood and resources such as grazing land, are owned collectively by the community (Mapiye, 2009). Pig production efficiency in these areas is generally low (Chimonyo *et al*., 2005). Under communal production system, pigs survive under unhygienic conditions with insufficient veterinary care, inadequate feeds and feeding management, and inefficient breeding management (Lekule and Kyvsgaard, 2003; Lemke and Zárate, 2008). Production system determines the type of pigs that can be raised by farmers under those prevailing conditions. The most common pig husbandry practices used in communal production systems include free ranging and backyard (Lekule and Kyvsgaard, 2003; Mashatise *et al*., 2005).

2.2.1 Free range production system

Free range is a form of husbandry where pigs are not confined indoors during the day and either penned or un-penned at night but are allowed to roam freely in the community (Mashatise *et al*., 2005). Pigs feed on kitchen wastes, brewery and cereal by-products, grass, plant roots and fruits (Lekule and Kyvsgaard, 2003). Free range pig production is practised by many communal farmers in rural areas of developing countries (Lekule and Kyvsgaard, 2003). Free range production systems save on labour since there is minimum management of pigs. It is a cheap system for resource-limited communal farmers since it allows pigs to off-set the seasonality of feed supply by going for alternatives such as roots, fruits and kitchen wastes. Pig genotypes that have foraging ability are likely to have higher value for communal production systems.

Free range production system allows sows for farmers who do not have boars to be mated and reproduce. Pigs kept under free range conditions, however, rely on low inputs and technology. As a result, the pigs have slow growth rates and low feed conversion efficiency (Chimonyo *et al*., 2005). Productivity is also compromised by the seasonal fluctuations in feed supply. In Zimbabwe, for example, most communal pig producers use the free range system during the dry season and the pigs are housed in simple pens during the rainy season (Holness, 1991; Mashatise *et al*., 2005; Chiduwa *et al*., 2008). The free range feed resource base limits the number of pigs per household and is a function of husbandry practices and nutritional value of the available feed (Chiduwa *et al*., 2008). In South Africa, the free range communal subsistence pig production is not the main source of meat supply for local consumption as also reported in Vietnam (Huynh *et al*., 2007). Free range pig production is one of the risk factors for outbreak and spread of diseases (Lekule and Kyvsgaard, 2003) as was the case with CSF in the Eastern Cape Province of South Africa in 2005. The government recommended that farmers enclose their pigs in specially built pens to minimise the risk of disease outbreaks. Given the farmers' financial constraints, government and local financial institutions are urged to assist pig producers with funding for the construction of proper pens that confine pigs indoors. Other communal farmers find it convenient to practise backyard production system for easy monitoring and feeding. It is, crucial to determine the economic values of the valuable adaptation traits that enable pigs to survive and reproduce under these systems.

2.2.2 Backyard production system

The backyard production system is a form of husbandry where pigs are kept inside a fenced yard and provided with supplementary feeds (Chimonyo *et al*., 2005). Commonly used feeds include rotten maize, hominy chops, coarse maize meal; maize husks, green maize, kitchen waste, vegetables, pumpkins, water melons, groundnut shells, fruits, grasses and brewers waste (Scherf, 1990). Although these feeds are high in carbohydrates and fibre, but low in protein, they are utilised efficiently by the slow-growing local pigs (Kanengoni *et al*., 2002). For example, feed needed by one imported pig genotype to produce a litter of 10 piglets is sufficient for two and half indigenous sows (Agricultural Research Council, 2010). There are, however, few communal farmers who afford to buy concentrates or straight feeds for their animals (Chiduwa *et al*., 2008; Madzimure *et al*., 2011). Most farmers are indigent and prefer pigs that do not require purchased feeds. In backyard production systems, genetic traits for survival may, therefore, be more important than those for production (Drucker *et al*., 2006). Estimating economic values on the lack of requirement for purchased feeds, is, therefore, crucial. The backyard production system seems to be a better option for improving productivity and minimising the risk of disease spread. Local pigs kept in different communal production systems have well defined phenotypic characteristics.

2.3 Phenotypic characteristics of local pigs

There are several local genotypes that are known in Southern African countries, the most common being Mukota, Kolbroek and the Windsnyer pig. In Zimbabwe, Holness (1991) and Chimonyo *et al*. (2008) described the Mukota pig in north-eastern part of the country. The Windsnyer (wind-cutter) genotype is found in parts of Mozambique, Northern Zimbabwe and the eastern parts of South Africa. These genotypes have similar phenotypic characteristics such as the long nose with a razor back (Halimani *et al*., 2010). In general, these local pigs are smaller and have longer legs than the imported genotypes. The mature weight of females ranges from 40 to 120 kg (Nengomasha, 1997). Local pig genotypes exhibit a typical unimproved conformation of a large head, well-developed forequarter and relatively light hindquarter (Holness, 1991). This renders them more mobile and better able to forage and root. There are many variations of coat colour but black and brown are most common and white is infrequent (Nengomasha, 1997; Ncube *et al*., 2003). The degree of hairiness varies, with some pigs being hairless or having relatively long bared types.

In South Africa, the Kolbroek (breech barkings), has also been reported as a local genotype but little has been done to characterise it [Farm Animal Conservation Trust (FACT), 2006; Halimani *et al*., 2010]. The Kolbroek is a short and fat pig with a short snout resembling the Chinese Lard pig (Nengomasha, 1997). Halimani *et al*. (2011) reported that all local pigs of Southern Africa are essentially one genotype based on molecular genetic characterisation.There are, however, few studies that have characterised communal pigs in Southern Africa. Local pigs have traits of economic importance that makes them favourable with communal farmers. These traits include small body sizes, heat tolerance, and production of tasty pork, good mothering ability of sows and excellent foraging ability.

2.4 Traits of economic importance in local pigs

Generally, local pigs in Southern Africa have favourable productive, behavioural and, sometimes unique, adaptive traits such as heat tolerance (Halimani *et al*., 2010). These attributes and the threats of loss due to disease outbreaks and replacement with imported genotypes make them suitable targets for conservation. Duguma *et al*. (2010) highlighted that there are distinct genotypes suitable for diverse purposes in the different production environments or ecological zones. As a result, farmers in different production systems have different trait preferences and the strategies followed by them are also as diverse as the agro-environments within which they operate (Duguma *et al*., 2010). To design a viable breeding plan, farmers' preferences for the different traits should be taken into account. Market-oriented farmers usually consider performance traits for profit maximisation, whereas subsistence-oriented farmers could value foraging ability more than growth performance (Roessler *et al*., 2008).

Local pigs have multiple adaptive traits to harsh environments, such as resistance to parasites and diseases, foraging ability, heat tolerance and temperament (Chimonyo *et al*., 2005; Marufu *et al*., 2008). These traits are often not reflected in the market prices of pigs and, hence, their values are unknown. There is little, if any, effort to attach a monetary value to each of these traits under different communal production systems of Southern Africa. As such, the TEV of these pig genetic resources is unknown. Without proper evaluation, their total economic value is likely to be underestimated and when compared to imported genotypes, local pigs continue to be sidelined. It is extremely difficult to design and implement utilisation and conservation strategies without knowing the economic value of local pigs. Knowledge of traits of economic importance leads to an understanding of functions and purposes of pigs hence the pigs' total economic value to communal farmers. The traits of economic importance for the local pigs are conveniently catergorised into production and adaptive traits.

2.4.1 Production traits

Growth rate, litter size, litter weight, feed conversion efficiency, meat quality, mothering ability and body conformation can be classified as production or performance traits. These traits determine the potential profit for the farmer and they are highly valued by the market-oriented production systems. Performance traits differ amongst pig genotypes and they can influence the farmer's choice of pig genotype to keep.

2.4.1.1 Litter size and litter weight

Literature on the reproductive performance of local pigs in Southern Africa is scarce. The Mukota pigs reach sexual maturity early compared to LW pigs (Holness and Smith, 1973). For example, females may show first oestrus as early as three months of age (Holness and Smith, 1973; Holness, 1991) while Mashatise *et al*. (2005) reported first oestrus at 150 days of age or 21 kg live weight. The reproduction cycle follows an annual rhythm, with the peak season of birth occurring during October (Holness and Smith, 1973). Age at first farrowing ranges from 6 to12 months and the farrowing interval is, on average, one year (Holness and Smith, 1973; Chimonyo *et al*., 2005). Under communal production systems, farmers place much importance on litter size or survival than litter weight (Chimonyo *et al*., 2008). Information on monetary values attached to reproductive performance of pigs under communal production systems is, however, not available.

The Mukota pig in Zimbabwe has a favourable litter size (7.9) compared to that of local pigs in South Africa (7.2), Nigeria (6.5) and Ghana (6.3) (Ndiweni and Dzama, 1995). Litter size for local pig genotypes is, however, small compared to that of imported genotypes (Chimonyo *et al*., 2008). The small litter size is attributed to high embryonic or foetal loss resulting from the small body size of the sows (Holness and Smith, 1973). Other factors that affect litter size at birth are nutrition, mating management and diseases (English *et al*., 1988). There has been little research on litter size in local pigs. Improved feeding and management of the local pigs could increase the number of foetuses produced at parturition, number born alive, number of piglets weaned and piglet birth weight (Holness and Smith, 1973). Piglet mortality is, however, above 10 % in communal areas because of the low external input flows (Chimonyo *et al*., 2005). The reproductive performance of the Mukota is likely to vary slightly with other local pigs of Southern Africa since they are one genotype (Halimani *et al*., 2011). The monetary value placed on litter size determines the choice of pig genotype to meet farmer's goals.

2.4.1.2 Feed utilisation efficiency

Local genotypes have less demand for feed because of their small body size when compared to imported pigs (Ndindana *et al*., 2002). These pigs can utilise fibrous and tannin-rich diets more efficiently than imported genotypes (Kanengoni *et al*., 2002; Mushandu *et al*., 2005). Ndindana *et al*. (2002) reported that tropical pigs, such as the Mukota, possess an abnormally long and large caecum-colon as well as a relatively large mass of the liver compared to imported pigs such as the LW. This could suggest that local pigs have a higher fermenting capacity and, therefore, explains their ability to digest large amounts of fibrous material (Dzikiti and Marowa, 1997). Kanengoni *et al*. (2004), however, reported a poorer feed conversion ratio (FCR) (amount of feed consumed to gain 1 kg body weight) of 6.3 for local Mukota pigs compared to FCR of 4.3 for the LW pigs when feed on high fibre diets. Feed costs are the major determinants of economic efficiency in a pig production enterprise (Klindt *et al*., 1999). Commercial feeds are unaffordable to resource-poor farmers even though the feed intake for the local pigs is low. The local pig genotypes subsist on low planes of nutrition, that is, low energy, low protein and high fibre (Ndindana *et al*., 2002). There is no information regarding the feeding standards for local pig genotypes (Chimonyo *et al*., 2005). Little research has focused on the nutritional value for locally available or non-conventional feed resources for the local pigs. Based on feed challenges, it is likely that farmers choose local pig genotypes that have superior foraging ability under communal production systems. Pigs with a good foraging ability support sustainable development for the resource-limited communal farmers. The monetary value attached to local pigs' foraging ability is, however, not known.

2.4.1.3 Growth rate

There are no reports on the growth measurements of local pigs under communal production systems mainly due to high costs and labour involved (Chimonyo *et al*., 2008). Slow growth rate is, perhaps, the supposedly major weakness of local pigs for commercial production. This slow growth can also be an adavantage under feed shortages as is the case in most communal production systems. Kanengoni *et al*. (2004) reported that Mukota pigs in Zimbabwe exhibit relatively low growth rates of 360 g/day compared to 660 g/day for LW pigs. Mukota pigs showed a peak growth between 12 and 14 weeks post-weaning (Kanengoni *et al*., 2004). In addition to the slow growth, local pigs mature early causing early deposition of fat than the fast growing imported pigs (Chimonyo *et al.*, 2005).

Local pigs in Southern Africa have an average mature weight of 100 kg although they are seldom reared to that weight (Chimonyo *et al*., 2005). Body weights at slaughter were reported to be higher in the crossbred than in the Mukota pigs (Chimonyo *et al*., 2010). Mukota pigs reach slaughter weight of 35 to 40 kg at six months of age while the LW pigs will be above 100 kg (Chimonyo *et al*., 2005). Further research should involve investigating the growth curves and development patterns of the local pig genotypes (Chimonyo *et al*., 2005). This will help in estimating their appropriate ages and body weight at slaughter. There is no information on the growth performance and monetary value placed on it under communal production systems of Southern Africa. The slow growth rate affects carcass yield and quality.

2.4.1.4 Carcass and pork characteristics

Local pigs of Southern Africa have poor body conformation (Mushandu *et al*., 2005; Chimonyo and Dzama, 2007). Kanengoni *et al*. (2004) reported cold dressed weights of 64 kg for LW pigs and 37 kg for the Mukota pigs at about 20 weeks of age. When the market demands minimum slaughter masses as part of the carcass grading scheme, local pigs could fail to meet the grade for pork, or achieve good grades (Kanengoni *et al*., 2004). Local pigs can deposit up to 30 mm of fat subcutaneously at the position 75 mm from the midline along the first rib compared to 11 mm for the LW pigs (Kanengoni *et al*., 2004). The fat deposit on Mukota carcass could be easily trimmed off to yield a leaner carcass and the fat or lard used for other functions such as cooking (Chimonyo *et al*., 2005). Trimmed fat is however, expensive and consumers do not want it.

The Mukota has a smaller eye muscle compared to the imported pigs and would be prejudiced against if either the P2 or K7.5 values are used for estimating carcass quality (Kanengoni *et al*., 2004). Mushandu *et al*. (2005) reported that local pigs produce good-quality pork (good eating quality) as that of imported genotypes if they are slaughtered at an early age. The local pigs tend to be discriminated against because of their short carcasses, which cannot be easily prepared into specialised pork portions (Chimonyo *et al*., 2010). Information regarding the dressing percentage, warm and cold carcass weight, eye muscle area, carcass length, body conformation and back fat thickness of local South African pig genotypes is not available. Moreso, the information regarding the monetary value placed on pork quality under communal production systems is missing. Pork quality can determine the preferred pig genotype by communal farmers. Generally, pork from Mukota pigs has been described as being organoleptically more acceptable to the rural people than pork from imported pigs (Ndiweni and Dzama, 1995; Chimonyo *et al*., 2005). The need to produce pork from free ranging pigs might increase the monetary value placed on those pigs with foraging ability.

2.4.1.5 Mothering ability

Local pig genotypes are generally known to have good mothering ability (Nengomasha, 1997; Chimonyo *et al*., 2008), although few empirical studies have been conducted. Mukota sows can be successfully reared without the need for farrowing crates (Mashatise *et al*., 2005). Mukota pigs possess superior genetically determined mothering abilities compared to imported pigs (Holness, 1991; Chimonyo *et al*., 2008). Chimonyo *et al*. (2008) suggested that good mothering ability makes the local pig suitable for communal production systems, where there is need to defend piglets from predators in free ranging pigs than those confined in commercial pig production. Communal farmers emphasise the importance of piglet survival either through good mothering ability or the inherent ability of the piglets to compete for resources (Grandinson *et al*., 2005). It is not known whether farmers in communal production systems select sows based on their mothering ability. In addition, the monetary value placed on it has never been reported.

2.4.2 Adaptive or survival traits

Adaptive traits for local pig genotypes are important especially under outdoor systems prevailing in communal production systems. Although welfare of the pigs is greatly improved under outdoor systems, imported pigs can not survive well under direct sun burn and disease challenges. Important survival traits valued by communal farmers include parasites and disease resistance, foraging ability, temperament and heat tolerance.

2.4.2.1 Resistance to parasites and diseases

Imported pigs in most communal production systems are vulnerable to gastro-intestinal parasites and diseases (Roepstorff and Nansen, 1994) because they are mostly scavenging for feed. The warm and humid conditions of the tropics and the inconsistent treatment of pigs against parasitic diseases (Mashatise *et al*., 2005) cause the pigs to harbour gastrointestinal nematodes (Holness, 1991). Gastrointestinal nematodes reduce pig production as they can result in the death of the animal, condemnation of carcasses during meat inspection (Zanga *et al*., 2003). Indirect losses due to the parasites include decreased growth rate, weight loss in sows and reduction in litter size (Marufu *et al*., 2008).

Mukota pigs of Zimbabwe are less vulnerable to gastro-intestinal parasites than imported pigs (Zanga *et al*., 2003). Marufu *et al*. (2008) reported that studies on parasite prevalence and impact in local pigs to Southern Africa are few. Chikwanha (2006) reported high mortalities in piglets as a result of high gastro-intestinal parasite loads. *Ascaris suum* is one of the important parasites that reduce pig production, as it reduces the digestion and absorption of nutrients (Zanga *et al*., 2003). The increased activity of alanine aminotransferase in LW pigs infected with *A. suum* suggests that *A. suum* larvae became established in them than in the Mukota pigs (Zanga *et al*., 2003). Based on that evidence, it was hypothesised that fewer larvae reached the livers of the Mukota than those of LW pigs. Local pig genotypes are, therefore, less susceptible to *A. suum* and, possibly, other important gastro-intestinal parasites.

Local pigs have been reported to survive outbreaks of ASF in Malawi and Mozambique (Haresnape *et al.*, 1987; Haresnape and Wilkinson, 1989). Halimani *et al*. (2010) suggested that it might be possible to select within the tolerant genotype for resistant pigs, introgress the resistance genes into their commercial fast-growing counterparts or identify genes for inclusion in other genotypes. It is, therefore, imperative to characterise pig genotypes to provide options for resistance to old, emerging and future diseases. The resistance might, however, not be genetic but a result of enzootic stability between the local pigs and the virus (Penrith *et al*., 2004). Local scavenging pigs have also been implicated in the spread of porcine cysticercosis (Lekule and Kyvsgaard, 2003), but this could be handled through good management practices (Halimani *et al*., 2010). The economic value placed on disease resistance is not known under communal production systems of Southern Africa. Research on this aspect can help increase the value of local pigs so that they do not continue being replaced with imported pigs.

2.4.2.2 Foraging ability

Foraging ability or the ability to scavenge involves the capability to search for food from the surroundings/environment (Chimonyo *et al*., 2005). Local pigs are usually kept out-doors and are not given any supplementary feed, hence they have developed the ability to look for feed from their surroundings than imported genotypes which are confined most of the times (Mashatise *et* *al*., 2005). Foraging ability is an advantage to communal farmers because they usually do not have sufficient money to buy feed and pay for labour to feed the pigs. Thus foraging ability of local pigs implies that there is reduced production cost for the communal farmers. Pigs produced in free range systems have the theoretical potential to forage on a variety of feedstuffs (Chimonyo *et al*., 2005). The Mukota pigs are kept under the free range system where they survive by scavenging (Mashatise *et al*., 2005) but such information is not readily available for the South African local genotypes. Local pigs scavenge for feed, in the process utilising kitchen wastes thrown away from households and fibrous materials such roots of plants. Foraging ability can be measured by the free ranging pig's ability to reproduce and maintain good body condition without any feed supplementation. Adaptability mechanisms linked with high foraging ability in local pigs are the long nose which allows them to forage on roots or insects beneath the soil and long legs for them to walk long distances in search of food. It is necessary to establish the monetary value that farmers attach to this important pig attribute under communal production systems.

2.4.2.3 Temparament

Pigs kept outdoors, as in the case of communal free range production systems, show calmer behaviour compared to most imported pigs kept intensively (Miao *et al*., 2004). In addition, imported pigs which are housed are aggressive against each other, moreso during feeding, whilst local pigs which are mostly scavengers have fewer interactions during feeding. Pigs that are aggressive can crush or savage their piglets, thereby, reducing the chances of piglet survival. The calmness of local pigs supports their good mothering abilities as reported by Chimonyo and Dzama (2007). Foury *et al*. (2005) showed that the levels of stress hormones, cortisol and catecholamines (adrenaline and noradrenaline); can be used to determine the relationships between stress-responsive neuroendocrine systems, carcass composition and pork quality. Such studies should also be conducted in local pigs.

2.4.2.4 Heat tolerance

Pigs have limited tolerance to high temperatures, such as those experienced in Southern Africa. The consequences of heat stress vary from reduced growth rates and carcass yield to poor meat quality and death (Gregory, 2010). Temperature humidity index (THI) can be used to indicate heat stress levels as done with dairy cows (Svotwa *et al*., 2007; Dikmen and Hansen, 2009). The frequency of drinking water per day can be taken as a proxy for heat tolerance in pig genotypes. Water consumption for the Mukota pig was reported to be very low (Nengomasha, 1997). For example, 6 litres per litter of seven is adequate weekly. Mud found in the free-ranging systems can coat the skin of the pig and prevent sunburn (Nengomasha, 1997). Local pig genotypes are speculated to be well adapted to the harsh tropical climate in the aspect of heat stress (Nengomasha, 1997). It is essential to determine the perceptions of the farmers on the extent to which local pigs tolerate extremes of temperatures and backup this information with impirical studies. The predominant black colour makes the local pigs less susceptible to sunburn compared to their imported counterparts (Chimonyo *et al*., 2005). The Ashanti Black Pig (ABP), which is local to Ghana, is also well adapted to tropical temperatures because it is resistant to sunstroke (Darfour-Oduro *et al*., 2009). The heat tolerance mechanisms for local pigs are, however, poorly understood. Pigs are thought to dessipate excess heat by varying their heart rate, body temperature, breathing rate, heart rate and behavioural activities such as wallowing (Bull *et al*., 1997; Zumbach *et al*., 2008). Most heat tolerance studies that have been done in imported pigs were using temperatures fixed at different levels (Patience *et al*., 2005; Huynh *et al*., 2005; Renaudeau *et al*., 2008), yet most heat stress experienced at a commercial farm is diurnal in nature.

The high temperatures in the tropics are ill-suited for the imported pigs as they depress appetite and, thereby, reduce growth performance (Miao *et al*., 2004). Information regarding the performance of Southern African local pigs under diurnal heat-related stress is, however, not available. Experiments that assess the effects of varying weather conditions reflect how the prevailing conditions influence pig production. The zones of thermal comfort in temperate regions, for the sow and piglet differ significantly; between 12 and 22 ˚C for the sow and from 30 to 37 ˚C for piglets, whilst for local pigs in the tropics, the values are higher. It could be important to determine the comfort zone for local pigs (Miao *et al*., 2004). Genetic improvement programmes targeting adaptive traits are important although these traits are known to have a low heritability (Hoffmann, 2010). The mechanisms for heat tolerance of the local pigs in Southern Africa are largely unknown. Further research is required to identify pig genotypes that can best survive under harsh environmental conditions and establish the economic value associated with heat tolerance of pigs under communal production systems. This information is required for future breeding programmes to consider all traits of economic importance to farmers. Understanding the importance of heat tolerance of pigs to farmers is important given the prospects of climate change (Fujisaka *et al*., 2010) and the threats it poses to the livestock industry.

2.5 Prospects for climate change

Gregory (2010) reported that the earth's near-surface temperature rose by 0.6 ˚C in the 20th century. It was estimated that half of that increase occurred due to greenhouse gas effects (Smith *et al*., 2007; Thornton *et al*., 2009; Gregory, 2010). In the future, dry places such as Southern Africa are going to be drier; than before, and temperatures are expected to rise by an average of 2.5 ˚C over the next forty years (Scholtz, 2009). It has been predicted that in some regions the weather will become more variable. For example, El Nino effect, fluctuations in the thermohaline circulation, and anomalies of ocean heat content could lead to short-term regional changes that are separate from a more general warming effect (Smith *et al*., 2007). High temperatures could create more variable extremes in weather pattern and they may have spin-off effects on the pork industry (Gregory, 2010). High temperatures could lead to relocation of pigs in some regions as these industries follow the sources of inexpensive cereals. In addition, where water becomes limiting through less precipitation, there could be less pig production (Hoffmann, 2010). There are many hazards linked to extremes in heat plus reduced rainfall on the livestock industry (Fujisaka *et al*., 2010; Oseni and Bebe, 2010), particularly pig production.

2.5.1 Effects of climate change-induced heat stress on pig production

Indirect effects of climate change include changes in ecosystems that affect distribution of animal diseases and feed (FAO, 2008; Fujisaka *et al*., 2010; Mirkena *et al*., 2010). Heat stress in pigs impairs not only the economics of the pig industry (St-Pierre *et al.,* 2003) but also the animals' welfare and environment (Huynh, 2005; Oseni and Bebe, 2010). Temperatures above the thermo-neutral zone (Renaudeau *et al*., 2008) can lead to loss of pregnancy in the first 30 days, failure of sows to express oestrous behaviour, an increase in stillbirths, reduced milk production and weight loss (McGlone *et al*., 1988; McGlone, 1999). Temperatures above 45 ˚C can be lethal (Hoffmann, 2010). The ambient air temperature plus the metabolic heat of the sow and piglets adds to the heat load inside the pig sty. In boars, ambient temperature above 29 ˚C causes heat stress and, consequently disrupts spermatogenesis (McGlone, 1999; Hoffmann, 2010). For 3 to 10 weeks after the heat stress experience, the boar may be infertile (Stone, 1982). Under a stressful environment, pigs reduce feed intake and conversion efficiency, which reflects changes in mechanisms that regulate metabolism (World Meteorological Organization (WMO), 1989). Reduced feed intake should be compensated by giving pigs diets of high nutrient density diets (Hoffmann, 2010). Ames and Ray (1983) reported that such changes result in alterations in the rate of energy transfer between the pig and its surrounding. Gregory (2010) reported that heat stress has direct effects on organ and muscle metabolism during heat exposure which can persist after slaughter. Heat stress, for instance, can increase the risks of pale-soft-exudative meat and dehydration in pigs (Pérez *et al*., 2002). Nevertheless, there is no consistent association between indices of stress and meat quality parameters (Bradshaw *et al.*, 1999). Further studies that elucidate the links among heat stress, pork quality and consumer acceptance in Southern Africa, are warranted.

2.5.2 Adaptation to climate change-induced heat stress

The prospects for global climatic change could mean that new adaptations may be needed for livestock to withstand greater extremes in temperature and rainfall (Drucker *et al*., 2000; Fujisaka *et al*., 2010; Oseni and Bebe, 2010). This requires a diversity of AnGR to be available. Specific adaptive attributes such as heat tolerance, drought tolerance, ability to efficiently utilise locally available feed resources (including fibrous and polyphenolic-rich substances) by local pigs could become even more important in the future. The influence of climate change and variability on livestock production systems is expected to be larger in the future than at present, especially in marginal areas (Mirkena *et al*., 2010; Oseni and Bebe, 2010). There could be a need to change the pig production system and use a diversity of livestock species. This is a result of the strong link with local environment and the limited access to technologies and financial support in marginal areas. Prospects of climatic change are further compounded by the fact that local pigs are adversely affected by environmental conditions (Lekule and Kyvsgaard, 2003). Researchable areas include assessing genotypes that have better thermal regulation capacity (Castanheira *et al*., 2010) or identification of genes associated with the acclimatisation of domestic animals to thermal stress (Hoffmann, 2010).

Local pig genotypes could be well acclimatised to the heat of the tropics, and hence can be used in breeding programmes to increase heat tolerance (Mirkena *et al*., 2010). Selecting heat tolerant genotypes might be of economic importance for communal farmers where most of the pigs are not housed but will be free ranging in direct sun. Hoffmann (2010) reported that optimum utilisation of the adaptation traits in local pig genotypes requires research into genetic characterisation and understanding of adaptation in stressful environments. The focus on conservation of the local pig genotypes is important given that they have multiple functions in communal production systems.

2.6 Functions and purposes of pigs in communal production systems

Local pigs have manifold non-market functions and purposes for communal farmers (Lemke *et al*., 2007). A genetic resource that has more functions and purposes might also have a higher total economic value for the farmer. Functions are considered to be the interactions of the animal with its environment (components of agro-ecosystem) as expressed through performance and behaviour (Drucker *et al*., 2000; Drucker and Anderson, 2004). Purposes (functions recognised and managed by livestock owners) are the reasons animal keepers have for keeping livestock based on a subset of their functions (Drucker and Anderson, 2004). The purposes for pigs for communal people can be put into four categories namely: socio-economic functions, production of goods, cultural and ceremonial roles and provision of services (Wilson, 1995; Doward *et al*., 2004). These roles can be dependent on location, with pig production away from town being less market-oriented (resource-driven) and fulfilling mainly saving, socio-cultural and consumption functions (Lemke *et al*., 2006). Near towns, pig production can be market-oriented (demand-driven), and hence have an income generation and provision of pork functions (Lemke *et al*., 2006). Livestock keeping by poor families in communal agriculture is multi-purpose, and imported pigs often do not have the attributes required to enable them to fulfill the multi-faceted roles they are allocated (Drucker *et al*., 2000). The establishment of pig functions is also paramount in understanding the economic values placed on pigs in communal areas. The functions of pigs are likely to vary among countries. Some of the major functions from other countries are reviewed below.

2.6.1 Socio-economic functions

The pig is a source of income, which can be realised at times of the year when major expenses are foreseen, and it can also be used as a 'savings bank', source of insurance, cyclic buffering, accumulation and diversification (Steinfeld, 1998; Anderson, 2003; Lekule and Kyvsgaard, 2003). In North Vietnam, for example, pigs contribute about 40 % of the cash income for smallholder farmers (Lemke *et al*., 2007). They are, therefore, available to be liquidated in times of need (Huynh *et al*., 2007). Pigs are usually sold when there is an urgent need for cash, such as paying for school fees, medical expenses, travelling, cultural celebrations and debts (Huynh *et al*., 2007). Pigs are also used as a means to generate and accumulate capital (Lemke *et al*., 2007). The capital accumulates through their reproduction. Pigs, like other livestock species, are inflation-proof and act as productive investments. Pigs are also important to diversify production, so as to reduce socio-economic risks (Devendra, 1993). They, therefore, act as a buffer to crop yield losses caused by droughts or excess rain. Lemke and Zárate (2008) reported that pigs in North Vietnam lost their saving function because pork for festivities was increasingly obtained from food markets.

Pigs provide security and self-esteem to communal farmers (Lemke *et al*., 2005). They give status and prestige to the owners and thus sustain social commitments and social networks (Lemke *et al*., 2005). As part of heritage, some societies may want to maintain historic activities and traditional livelihoods (Mendelsohn, 2003). Pigs are also slaughtered at ceremonies and rituals (Lemke *et al*., 2006). In North Vietnam, butchered pigs were used for worshipping ancestors or as a sacrifice, as a gift, or payment for hired workers (Lemke *et al*., 2006). Local pigs are also kept as pets in many African societies (Epstein, 1983). The Bateke people of Gabon, for example, keep a favourite boar as a friend for the whole village (Epstein, 1983).

Pigs form integral components of mixed crop-livestock farming systems. They provide manure or cash for the purchase of inputs for crop production. In other countries, like Zimbabwe, some by-products such as pig manure can be sold to generate income. Pigs allow the poor to obtain benefits for their families from exploiting common property when they are free ranging. Local pigs can also utilise resources that have few alternative uses, such as agricultural by-products (Ellis *et al*., 1997). Research is needed to establish if pigs have monetary values for their social functions as was reported for chickens by Faustin *et al*. (2010).

2.6.2 Production of goods

The most direct benefits of local pigs are those related to food supplies and other goods such as manure. Through formal interviews, Mashatise *et al*. (2005) reported that over 70 % of farmers in north-eastern Zimbabwe kept pigs primarily as a source of meat. Farmers also value fat that is obtained after slaughtering pigs. The fat is normally used for cooking. China and South East Asia, for example, keep pigs for the production of lard (Epstein, 1983).

The manure that is produced by pigs can be used to generate biogas and the residue can be used as fertiliser for crop production (Thorne and Tanner, 2002). The biogas is used as fuel, which could be used for cooking purposes. In this way, households can double the value of what is otherwise a waste product. Pig manure is useful in fertilising fish ponds as slurry. Farmers are able to attach monetary values to goods they get from pigs although such information is not available in Southern Africa, thereby warranting further research.

2.6.3 Provision of services

Pigs are essential in the provision of services to communal households. Local pigs can be part of local landscapes and environments that society wants to maintain (FAO, 2007). They dispose of garbage and can be used as agents in the establishment and maintenance of tall grass fallows.

The Iberian pigs have been commended for maintaining the *dehesa* (wooded pastureland ecosystem) which has been declared a Biosphere Reserve by UNESCO (FAO, 2007). The use of manure as generator of fuel (biogas) may put less pressure on forests, thereby reducing deforestation and environmental degradation. Pigs promote linkages between systems and resource components (land, water, crops and animals) (Huynh *et al*., 2007). This synergistic interaction between livestock and crops improves the sustainability of the farming system and maintains or improves soil fertility. It is not known whether farmers place a monetary value in the provision of services by pigs under communal production systems.

The knowledge of functions of local pigs help to understand the economic value placed on them by communal people. Basing selection of pig genotype on financial returns alone result in continued discrimination of local pigs in favour of imported pigs which grow fast and have higher returns. Farmers select pig genotypes that have desirable attributes to complement their functions in different communal production systems. Multiple functions of local pigs may imply that they have higher value to communal farmers than the imported genotypes. Despite these diverse functions for local pigs, they are threatened by many challenges.

2.7 Threats to local pigs and the need for conservation

Conservation of local pig genetic resources is necessary because of their unique traits which serves multiple functions and because many communal livelihoods depend on these functions, in particular in developing countries. In addition, these pigs require minimal level of management compared to the imported pigs. Pigs are a source of livelihood for communal farmers and they ensure food security. There is, however, the challenge of getting support for conservation of local pig genotypes from commercial farmers who view extensive production as unproductive. In Zimbabwe, only a few institutions are conserving small herds of Mukota pigs (Chimonyo *et al*., 2005). Although local pigs are thought to be endowed with unique performance and adaptation attributes, extensive uncontrolled breeding with imported breeds have resulted in genetic erosion of the local pigs. The genetic erosion will, undoubtedly, culminate in the reduction of fitness traits making pigs susceptible to diseases and other environmental stresses (Nengomasha, 1997). In general, local pig genetic resources in communal areas of most Southern African countries are threatened by sporadic disease outbreaks, replacement with imported genotypes, indiscriminate crossbreeding, lack of well defined policies on the utilization of local livestock genetic resources, lack of information (Halimani *et al*., 2010) and erosion of rural culture.

2.7.1 Replacement with imported pigs

The focus for increasing communal pig production has been on the introduction of imported pigs that have been artificially selected for few productive traits such as fertility (Drucker *et al*., 2000). In South Africa, imports and exports of animals are regulated by the Animal Improvement Act of 1998 (FAO, 2007). The introduction of imported pigs has, therefore, led to the dilution of local pig genotypes and the destabilisation of the traditional livestock production systems (Chimonyo *et al*., 2005). The extent of the dilution is not known since there is no record keeping in communal production systems. Pig genotypes are easily irretrievably lost when they are considered to be commercially non-competitive (Philipsson and Okeyo, 2006). FAO (2007) estimated that the rate of extinction of domesticated animals is accelerating. Lack of interest in the local genotypes can also be caused by subsidies being provided to keep improved genotypes (Rege and Gibson, 2003). This is often caused by externally biased agents of change (such as national extension workers, and foreign donors) actively supporting commercial farmers only (Mendelsohn, 2003; Drucker *et al*., 2006). In Southern Africa, communal pig production is poorly supported (Mashatise *et al*., 2005). Establishing the total economic values for local pigs may help to explain if their replacement with imported pigs is justified.

2.7.2 Indiscriminate crossbreeding

Local pigs are often crossed with imported boars to take advantage of heterosis. If the genotype is rare, dilution of genotype characteristics results from indiscriminate crossbreeding. It will then be difficult to identify and utilise the genotype's genetic characteristics. Upgrading is also practised to improve the performance of the local genotypes. This leads to loss of environmental adaptation and, in most cases, the purebreds of the local genotypes are not maintained. Indiscriminate cross breeding programmes are, therefore, likely to undermine the economic value of the local pigs in communal production systems. When appropriately utilised in pure or crossbreeding programmes, local pigs can contribute to increased productivity in communal production systems (Philipsson and Okeyo, 2006). Halimani *et al*. (2010) reported that most Southern African countries do not have clearly defined pig crossbreeding programmes. Malawi is the only country that tried to embark on a crossbreeding programme in the 1950s without success (Safaloah, 2001). It is recommended that research institutions and universities take lead in appropriate crossbreeding programmes and sell the stock to communal farmers. These institutions should also offer backup services to advise farmers, identify markets and genotype replacement stock.

2.7.3 Sporadic outbreaks of disease and parasites

Local pig genetic resources in Southern Africa are under threat from sporadic disease outbreaks, such as CSF in the Eastern Cape Province of South Africa and ASF in Malawi and Mozambique (Halimani *et al*., 2010). The outbreak of CSF in South Africa (WOAH, 2005) led to the culling of more than 335 000 pigs (more than two thirds of the pig population in the Eastern Cape Province) and a loss of 95 % in production (NAFU, 2007). Halimani *et al*. (2010) correctly indicated that the current restocking efforts are not likely to replace the lost biodiversity. There is room to select and conserve local pig genotypes and individuals that are resistant to diseases and parasites. This will help increase the economic value for local pig genetic resources especially for the communal production systems. Breeding for disease resistance is, however, difficult under communal production systems unless research institutions and universities lead the process.

2.7.4 Erosion of rural culture and lack of information

The erosion of rural or traditional cultures leads to loss of indigenous knowledge on the husbandry of local pigs and the recognition of their value (Chimonyo *et al*., 2005). Loss of traditional culture also leads to the homogenisation of consumption patterns, which often causes a preference for imported pig products. Closely tied to loss of culture are changes in livestock production systems that can cause genetic erosion of local pig genotypes (Halimani *et al*., 2010). This has been worsened by lack of research on local pig genotypes to highlight their potential under communal production systems where they are commonly found. There is need for characterisation of local pig genetic resources as a first step to their conservation. Documenting the characteristics of local pigs that make them ideal for communal farming may result in better understanding of the farmers' breeding goals that shape these animals. Breeding goals in communal areas also include aesthetic preferences, such as preferred colour and colour distribution, behavioural aspects, such as a complacent nature, good mothering instincts, and having a sense of home and loyalty to the owner. More importantly, the ability to survive natural calamities, such as droughts could be more important than high productivity for communal farmers (Roessler *et al*., 2008).

2.7.5 Inappropriate agricultural policies

Poorly planned conservation practices can lead to genetic erosion of local pigs. This could be due to intense inbreeding in the small populations, inadequate storage of genetic materials and *ex-situ* conservation, which often causes loss of adaptation traits. Halimani *et al*. (2010) reported that most Southern African countries do not have coherent policies for the conservation of pig genetic resources and reward systems for participants. Only South Africa has clearly defined policy on conservation, although serious challenges exist in its implementation. There is lack of infrastructure to match the stipulated conservation measures. In South Africa, property rights related to biodiversity protection and conservation are managed by the Biodiversity Act number 10 of 2004 (FAO, 2007). A clearly defined policy should define genotypes that are endangered or are key in the livelihoods of the majority of the people hence should be prioritised in conservation. South Africa believes keepers of local pigs should be supported in terms of service delivery for their contribution to the conservation of animal genetic resources (FAO, 2007). Lack of clearly defined policies has been the sole reason for the collapse of the pig crossbreeding programme in Malawi. There are many factors that threaten the existence of local pig genetic resources but the governments need to take a proactive role in promoting these pigs. This can be done through enacting appropriate policies and supporting structures that stimulate conservation of pig genetic resources. Provincial governments of South Africa are not doing enough to support conservation of local pig genotypes.

2.8 Conservation of local pigs

Farmers have a wealth of indigenous knowledge (IK) that should be tapped to enhance culturally appropriate and sustainable conservation of local pig genetic resources (Homann *et al*., 2008). Conservation of pig genetic resources describes the identification, monitoring, characterisation and utilisation of pigs for best short term use and to ensure management for longer term availability (FAO, 1993). The need for conservation is greater when the size of the population is getting smaller as is the case with local pigs in Southern Africa. The endangerment of a genotype can be described as critical, endangered or extinct (FAO, 2007). The local pig genetic resources have not been officially declared as endangered, although little, if any, empirical research has tried to establish their risk status. The costs associated with the loss of local pig diversity involve the loss of direct use, indirect use and non-use values (Drucker *et al*., 2006). As local pig genotypes are well adapted to the extensive production systems, they represent the important livestock genetic resource for poor farmers in communal areas. Local genotypes have distinct genetic make-up which means that they also have useful traits (and hence option values) for future breeding programmes and production system evolution (Drucker *et al*., 2006). The local pig genotypes offer an insurance value for the communal people during a crisis because of their diverse genetic make-up. Shocks such as droughts, floods, wars, social unrest, advent of new or sporadic diseases and epidemics can all call for the need for agro-biodiversity (Patterson and

Silversides, 2003). The loss of local pig genetic resources reduces opportunities for poverty alleviation and improved food security (Halimani *et al*., 2010).

The increasing demand by consumers to purchase pork from extensive production systems raises awareness about the requirement for adaptable local genotypes. In the United Kingdom, for example, farmers were forced to shift from indoor to outdoor pig production systems (Drucker *et al*., 2000). This modification requires new digestive adaptations to accommodate grass feeding. In addition, the ability to partition more nutrients to fat will be needed to weather cold temperatures. Changes in production systems could also affect other countries including those in Southern Africa. Such changes require the availability of diversity as is presented by local pig genotypes. To ensure sustainability of local pig genotypes, it is important to look at the conservation options that are available.

Conservation of AnGR can either be *ex-situ* or *in-situ*. Ex-situ methods of conservation include conserving the genetic material and the preservation of genetic information (FAO, 2007; Halimani *et al*., 2010). It includes the maintenance of small populations in domestic animal zoos, cryopreservation of semen, ova or embryos (FAO, 2007). *Ex-situ* conservation also encompasses the preservation of genetic information such as deoxyribonucleic acid (DNA) stored in frozen blood samples or as DNA segments (Halimani *et al*., 2010). In the Southern African region, only South Africa is better equipped with both personnel and laboratories to carry out molecular characterisation techniques that can aid in *ex-situ* conservation research (Halimani *et al*., 2010). The conservation of live populations in their adaptive environments is called *in-situ* conservation (FAO, 2007).

In situ conservation is the preferred method for pig genetic resources in most Southern African countries because it allows genotypes to continue evolving with their environments (FAO, 2007). The basis for *in-situ* conservation is that local pig genotypes are products of specific ecological and cultural environments, and their genetic make-up and integrity will be affected if they are removed from their original contexts (FAO, 2007). Transfer of domestic animal populations into controlled environments poses the danger of the gradual erosion of their adaptive traits. *In-situ* conservation allows for comparative trials, research, selection and improvement, and adaptation to the changing environmental conditions (Halimani *et al*., 2010). Conservation of local genotypes, therefore, requires the active support of the farmers who own and utilise these pigs. The active involvement of farmers in the conservation of animal genetic resources is commonly known as community-based management of animal genetic resources (CBMAnGR) (Drucker *et al*., 2006). Halimani *et al*. (2010) stated that Southern Africa lacks the resources to develop *in-situ* conservation programmes. To ensure sustainable conservation programmes, there is need to value local pig genetic resources.

2.9 Principles of economic valuation of local pigs

Environmental valuation techniques can provide useful evidence to support and justify conservation policies by quantifying the total economic value associated with the protection of biological resources. Environmental valuation is about preferences and utilities for environmental goods and services and revealing their total economic values (Louviere *et al*., 2000). Economic theory suggests that decisions such as the replacement of a local pig genotype with an imported genotype are determined by the utility or welfare they give to farmers (Drucker *et al*., 2006). Drucker *et al*. (2006) reported that the loss of local pigs to the farmer may appear to be economically rational if returns are higher than that from activities compatible with genetic resource conservation, especially since the latter may consist of non-market benefits that accrue to people other than the farmer. Quasci-public goods are essentially public in nature, but do not exhibit fully the features of non-excludability and non-rivalry (Riley, 2006). When a quasi-public good like pig genetic resources generates economic values that are not captured in the market place, it results in a distortion where the incentives are against genetic resources conservation and in favour of the activities that erode such resources (Pearce and Moran, 1994). The pigs, however, are private goods (Scarpa *et al*., 2003).

Lack of economic values for local pigs has led to the lack of appreciation of their economic roles, which, thus, endanger their existence as a genotype and the livelihoods of communities that depend on them. The social and cultural values of traits for local pigs are not captured in the market place (Roessler *et al*., 2008) and yet they can be identified. Market failures such as the quasi-public good character and externalities lie at the heart of any explanation for the loss of local genotypes. With a quasi-public good, one can easily keep nonpayers from consuming it but use of the good by one person does not prevent use by others (Zander *et al*., 2009). The challenge is, therefore, to quantify the values that are attributable to local pig genetic resource. Correct valuation can make people decide between genetic erosion or destruction of local pig genotypes and their conservation (Pearce and Moran, 1994).

The large number of AnGR and livelihoods at risk in developing countries, together with limited financial resources available for conservation, mean that economic valuation can play an important role in ensuring an appropriate focus for conservation efforts (Drucker *et al*., 2000).

Establishing economic values for local pig genetic resources can contribute to policy and management decisions. This information can be of interest to farmers' rights activists who want measures of the local pig value in order to calculate compensation to farmers (Drucker *et al.*, 2000).

According to Pearce and Moran (1994), the value of a genetic resource can be estimated by the equation:

TEV = DUV + IUV +OV +BV +XV; where:

TEV = total economic value of a genotype,

DUV = direct use value emanating from direct uses such as meat and manure,

IUV = indirect use values, which are benefits from the ecosystem e.g. pigs dropping faeces on grasses or the dispersion of plant species,

OV = option values that are derived from safeguarding an asset for use at a future date. Option values can be viewed in the light that local pigs in communal production systems are a form of insurance against the occurrence of shocks such as new diseases and climatic change,

BV = bequest values that measure benefits that accrue from the knowledge that other people might benefit from the resource or the wish to be able to pass something to one's descendants,

XV = existence values that are derived from the satisfaction that a particular asset exists e.g. historical purposes or because of aesthetic considerations such as beauty or toughness.

In the context of AnGR, the values for IUV, OV, BV and XV can be more important or equal to DUV. The emphasis and focus on DUV alone mean that local pigs have no exchange values that reflect their economic scarcity. The equation does not, however, incorporate all the benefits of local pigs as perceived by farmers. For example, it is unclear where cultural values fit, though they are likely to be incorporated under indirect use values from the perspective of farmers. There are numerous methods for estimating TEV (Bateman *et al*., 2003). These include contigent valuation and choice experiments.

2.10 Methods for economic valuation of pigs

Several methods have been developed for the valuation and pricing of environmental goods. The methodologies that can be applicable to the valuation of AnGRs can be grouped into two major categories namely; stated preference (SP) and revealed preference (RP) methods (Freeman, 2003; Louviere *et al*., 2000). Stated preference methods are applied if no market data is available but a hypothetical market is created. The methods include choice experiment (CE) and contingent valuation (CV). Revealed preference methods, such as travel cost method and hedonic pricing, can be applied when market transactions can be observed. Pricing methods include everything else, where indirectly a value is assigned, like production function approach and opportunity cost approach. Only SP methods are able to capture the TEV (Pearce and Moran, 1994). Both CV and CE methods involve the survey of attitudes, and the values are expressed as farmers' willingness-to-pay (WTP) for certain environmental goods or services or willingness-to-accept (WTA) compensation for forgone goods/services (Freeman, 2003). Both methods are survey-based and hypothetical markets are created in which respondents are asked to trade-off money for the environmental good/service (Louviere *et al*., 2000).

2.10.1 Contingent valuation

Contingent valuation is a survey-based technique for the valuation of non-market resources which was first proposed by Ciriacy-Wantrup in 1947. The first practical application of the technique was in 1963 when Davis used surveys to estimate the value hunters and tourists placed on a particular wilderness area. Early work using CV suffered heavy criticism prompting the set up of a panel of prominent social scientists in 1992 by the National Oceanic and Atmospheric Administration (NOAA) to come up with guidelines for dealing with natural resource damage (Carson *et al*., 1995). The panel agreed that CV should use a referendum approach where each person is asked how they would vote when faced with a particular program and prospect of paying for the programme (Carson *et al*., 1995). This technique resulted in direct elicitation of non-use values from individuals through the use of carefully designed and administered surveys. Contingent valuation may be better suited to situations where changes in the total economic value of a non-market good are at issue, or where environmental resources are hard to describe using attributes (Carson *et al*., 1995). The CV method has been applied extensively in valuing ecosystems/landscapes such as freshwater and forest (Spash, 2002) and to some extent endangered animal species (Bateman *et al*., 1992; Drucker *et al*., 2000; Cicia *et al*., 2003).

Contngent valuation has a number of advantages. It is very flexible, can be used to estimate the economic value of all things that can be easily identified and understood by users. The CV method is widely accepted for estimating total economic value because it estimates use values, existence values, option values and bequest values (Freeman, 2003). Even the results are not difficult to analyse and describe provided they have been properly collected.

The CV technique has, however, received a lot of criticism as outlined by Carson *et al*. (1995). Firstly, it is difficult to distinguish the value of each characteristic of a multi-attribute good (Bateman *et al*., 2003). In the case of pigs, it means respondents only state one value for pigs and it will be difficult to determine the contribution from use-values and non-use values (Zander, 2006). The method sometimes gives results that are implausibly large or inconsistent with rational choice (Carson *et al*., 1995). Previous CV studies failed to forcefully remind respondents of the budget constraints they should operate within (Bateman *et al*., 2003). The other problem might occur when generating aggregate demand where it may be difficult to determine the extent of the market (Carson *et al*., 1995). Lastly, respondents in CV survey may actually be expressing feelings about public spiritedness rather than actual willingness to pay for a programme in question (Freeman, 2003). The WTP value can be affected by embedding or place where something has been placed in the list of things to be valued (ordering problem) (Freeman, 2003). Based on the limitations of the CV technique, the CE method has evolved to mitigate some of the biases.

2.10.2 Choice modeling

Choice experiments and choices ranking (CR) are methods used for estimation of the value of the public good as a whole, like CV, but also, unlike CV, of the implicit marginal values of its attributes (Hanley *et al*., 1998; Bateman *et al*., 2003). While CV directly asks respondents to state their values, CE is an indirect method. Choice experiments are grounded on Lancaster's theory of consumer choice (Lancaster, 1966), stating that consumers derive utility not from the good *per se* but from the bundle of attributes and magnitude (levels) of the attributes they provide. McFadden (1974) stated that the methods are further based on the random utility theory

(RUM), which illustrates that utility for a consumer derived from a good consists of an observable and deterministic part, and an unobservable part. Choice modeling posits that with human choice there is an underlying rational decision-making process and that this process has a functional form (Ngapo *et al*., 2010). The multinomial logit (MNL) model form is commonly used as it is a good approximation to the economic principle of utility maximisation. The MNL form describes total utility as a linear addition (or subtraction) of the component utilities in a context. Once the functional form of the decision process has been established, the parameters of a specific model may be estimated from available data using multiple regression, in the case of MNL (Louviere *et al*., 2000).

Choice experiments involve use of questionnaires in which respondents are given a set of hypothetical alternatives, each depicting a different situation with respect to some environmental or public good with its attributes and are asked to select or to rank the alternatives according to their preference (Hanley *et al*., 1998; Duguma *et al*., 2010). Traits of economic importance will be evaluated in a CE from the perspective of the utility they generate (Scarpa, 1999; Drucker and Scarpa, 2003) for communal livestock-keepers.

A CE on Mexican pigs revealed that farmers were interested in weight increase, feed costs, disease resistance, and bathing frequency (Drucker and Anderson, 2004). Kenyan cattle farmers valued weight, condition, some breeds and sex (Scarpa *et al*., 2003; Ouma *et al*., 2004). It is crucial to ensure a good CE design by ensuring that the choice of attributes, the levels chosen to represent them, and the way in which choices are relayed to respondents (for example, type of visible aid, explanation, the quality of enumerators) are properly done (Zander, 2006). These factors impact on the values of estimates of consumers' surplus and marginal utilities. Wurzinger *et al.* (2006) reported that CE are important for identifying selection criteria in communal production systems where literacy level is low and recording practices are not in place. It is recommended to reduce the choice tasks to a manageable level (seven and below) to avoid fatigue in respondents and ensuring quality output (Bateman *et al.*, 2003).

There are many advantages of using CE designs. Firstly, CE can avoid multi-collinearity problems that often arise in revealed preference analyses based on variations in actual attribute values across goods (Bateman *et al*., 2003) because of the fractional factorial orthogonal designs. In addition, CE forces respondents to consider trade-offs between attributes. The frame of reference is made explicit to respondents via the inclusion of an array of attributes and product alternatives (Freeman, 2003). Choice experiments enable implicit prices to be estimated for attributes and welfare impacts to be estimated for multiple scenarios (Adamowicz and Boxall, 2001). Lastly, CE can be used to estimate the level of customer demand for alternative 'service product' in non-monetary terms; and potentially reduces the incentive for respondents to behave strategically (Bateman *et al*., 2003; Freeman, 2003). The setback to CE is that it is very sensitive to experimental design and other attributes may not be included in the model yet they generate utility (Freeman, 2003). It is also questionable that the value of the "whole" is, indeed, additive. There can be inconsistent responses as the number of choices increases (Bateman *et al*., 2003). Despite its disadvantages, the CE has remained a valuable tool for non-market valuation of environmental goods.

2.11 Summary

The outbreak of CSF posed a threat to the erosion of local pig genetic resources of Southern Africa. Designing restocking programmes for pigs without establishing the perceptions of the communal farmers is likely to cause passive resistance and prohibit co-operation by the communities. The review of literature established that local pig genotypes can be maintained in marginal farming areas, thereby increasing sustainability and food security. For local pig genotypes to retain their adaptability, they should be conserved *in-situ*, with the active participation and involvement of the communal pig farmers. Active participation assists in extracting their indigenous knowledge, on which technologies should be developed. The potential of local pig genotypes in developing countries is often inadequately documented and utilised. No studies have established the threats posed climatic change effects on the welfare of local pigs. Identification of pig genotypes that have superior heat tolerance mechanisms and growth performance under diurnal heat-related stress is of paramount importance for sustainable development in low-input systems. Conservation of adapted local pig genotypes requires determination of their true TEV. The value of local pig genetic resources conservation is generally underestimated, as the current indirect values are often neglected; the future option values are yet to be accurately estimated and predicted, yet the most efficient way to sustain a pig genotype is to continuously keep it commercially competitive or culturally viable. Research and capacity building to improve the knowledge of local pig genetic resources in communal production systems is important. Thus all goods and services obtained from pigs by rural communities need to be investigated through the use of choice experiments. The broad objective of the study was, therefore, to determine the economic worth of the adapted local pigs in communal production systems to the resource-limited farmers of Southern Africa.

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CHAPTER 3: Farmer perceptions of disease outbreaks in communal pig production systems of South Africa

(Submitted to *African Journal of Agricultural Research*)

Abstract

After the outbreak of CSF which resulted in culling of about 335 000 pigs in South Africa, policy makers are expected to make decisions on the restocking of pigs by the communal farmers. The objective of this study was to investigate farmer perceptions, effects on pig production and handling of disease outbreaks in market- and subsistence-oriented production systems that were either inland or coastal. Data were collected from 288 farmers in two CSF-affected areas (one market-oriented production system on the coast, one inland subsistence-oriented production system) and one CSF-unaffected area (subsistence-oriented production system on the coast). In CSF-affected areas, there were more market-oriented farmers (89 %) than subsistence-oriented farmers (73 %) who kept their local pigs and non-descript crosses with imported pigs on backyard production system. In subsistence-oriented production system which was not affected by the CSF outbreak, 66 % of farmers were using free range rearing systems while the rest were using a backyard rearing system. Significantly more pigs were culled per household in the coastal market-oriented production system that was CSF-affected (8 ± 1.76) than inland subsistence-oriented production system (4 ± 1.00) ($P < 0.05$). Famers (62 %) in both production systems reported that culling of pigs affected pork availability and income generation, and caused ecosystem disturbance in the crop-livestock production systems. The risk of pig parasites and disease challenges was highest for subsistence-oriented production system followed by pigs owned by heads of households who were not staying on the farm and coastal areas. To facilitate restocking and conservation of local pig genetic resources, farmers in both production systems requested development agents to assist with loans (28 % of farmers), breeding stock (78 %), proper housing structures and improved extension services (60 %). Farmers in both market-oriented (88 %) and subsistence-oriented production systems (64 %) perceived CSF as destructive to pigs thereby jeopardising their source of income and pork.

Key words: Pig genetic resources, Conservation, Disease outbreaks, Pig culling, Restocking.

3.1 Introduction

Sporadic disease outbreaks pose a threat to the erosion of biodiversity for local pigs of Southern Africa (WOAH, 2005; Halimani *et al*., 2010). For example, the outbreak of CSF led to the culling of more than 335 000 pigs in South Africa (SAPA, 2005; NAFU, 2007). The loss of pig biodiversity affects the ability of future breeding programmes to respond to changing climate and consumer needs. Halimani *et al*. (2010), for example, highlighted that any future restocking efforts are not likely to replace the lost biodiversity. Culling left few breeding males and females, thereby increasing the chances of related pigs to mate each other resulting in inbreeding. It is, therefore, important to understand the impact of diseases in communal production systems, and tap on the indigenous knowledge on how to minimise their devastating effects. Any intervention to reduce the impact of diseases assists in the conservation of pig genetic resources and promotes sustainable rural development.

Most of the pigs that were culled during the 2005 CSF outbreak in South Africa were from areas located along the coast, perhaps because of the pattern of spread of the disease which emanated from a coastal town of Centane (Department of Agriculture, 2006). The sampling of households for the current study was, therefore, designed to represent the coastal and inland areas (which were either in market- or subsistence-oriented production systems) of the Eastern Cape Province of South Africa. Coastal areas are thought to harbour many diseases because of the hot humid conditions when compared to inland areas (Rowlands *et al*., 2007; Jutla *et al*., 2010; Ortiz-Pelaez *et al*., 2010). The type of production system is related to the wealth status of the farmers and their ability to cope with risks such as disease outbreaks (Langyintuo and Mungoma, 2006). No studies have attempted to establish farmer perceptions on CSF disease outbreaks and their effects on market- and subsistence-oriented production systems in inland; and coastal areas.

Restocking of commercial pigs is generally easy to implement, as imported pigs are widely available from renowned pig breeders. Sourcing of local pigs after culling is, however, extremely difficult because there are no breeders. Designing restocking programmes for pigs without establishing the perceptions of the communal farmers is likely to cause passive resistance and prohibit co-operation by the communities. There is risk of disease outbreak if farmers are left to restock using some of the pigs that were hid during the culling exercise. The objectives of the current study were to investigate farmer perceptions, effects on pig production and handling of disease outbreaks in market- and subsistence-oriented production systems in coastal and inland areas. The hypothesis that was tested was that farmer perceptions, effects on pig production and handling of disease outbreaks in market- and susbsistence-oriented production systems in inland and coastal areas were similar.

3.2 Materials and Methods

3.2.1 Study sites

The study was conducted in communal production systems of Elundini (CSF-affected, subsistence-oriented and inland), Ntabankulu (CSF-unaffected, subsistence-oriented and coastal) and Ngqushwa (CSF-affected, market-oriented and coastal) municipalities in the Eastern Cape Province of South Africa (Figure 3.1). Communities in Ngqushwa Municipality were producing pigs for commercial sale to abattoirs, supermarkets or butcheries in the nearby King Williams (20 km) and Peddie (3 km) towns. Farmers in market-oriented pig production system were buying supplementary feeds and obtained more income from pigs. Elundini and Ntabankulu Municipalities composed of rural communities that were resource-limited and raised pigs on free ranging mainly for household consumption or selling in the neighbouring households. The sites were chosen after the CSF outbreak and policy makers needed data to restock pigs in the Eastern Cape Province. The sites were selected with participation of State Veterinary Services, University of Fort Hare, councillors, farmer representatives and government officials. In the whole of the Eastern Cape Province, Ntabankulu was the only municipality where pigs were not culled because the pigs tested negative against CSF.

In addition, farmers in Ngqushwa Municipality are generally market-oriented when compared to the subsistence-oriented farmers in Elundini and Ntabankulu Municipalities. Elundini Municipality is situated 28° 25′ E; 30° 26′ S with an elevation of about 1600 m above sea level. The mean annual rainfall ranges from 800 to 1200 mm. The area has average minimum day temperature of 13 $^{\circ}$C and maximum temperature of 22 $^{\circ}$C. Ngqushwa Municipality is situated 27° 7′ E and 33° 12′ S. The temperature ranges from -2 $^{\circ}$C to 42 $^{\circ}$C with an average of about 18 $^{\circ}$C.

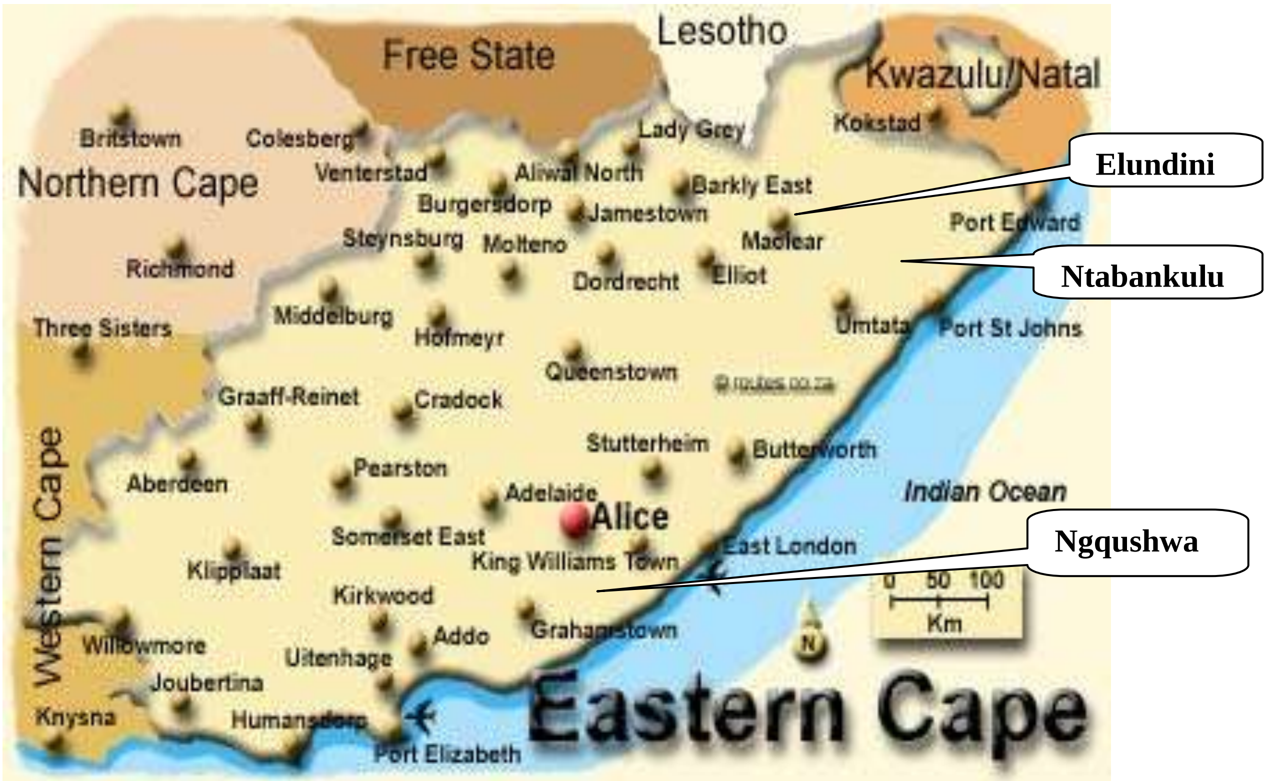

Figure 3.1: Map showing study sites in the Eastern Cape Province of South Africa

The area receives an annual rainfall of about 450 to 900 mm with most of it occurring in summer. The area has deep loamy soils with vegetation greatly covered by the *Acacia karroo.* Ntabankulu Municipality is situated 29° 16′ E; 31° 04′ S with an elevation of about 476 m above sea level. Ntabankulu receives mean annual rainfall of 620 mm with most rainfall occurring during mid-summer. Average daily temperature ranges from 17.8 °C in June to 25 °C in January.The municipalities were representative of most communal areas in Southern Africa where pigs form integral components of mixed crop-livestock farming systems by providing manure or cash for the purchase of inputs for crop production. The municipalities were also chosen to get an insight into farmers' perceptions in CSF-affected and non-affected communal production systems.

3.2.2 Data collection

Data CSF outbreak were collected from three municipalities using individual structured questionnaires (Appendix I), in-depth interviews with key informants and direct observations of pigs and production practices. Primary information about disease outbreaks and pig production was obtained from key informants. Extension officers, veterinary specialists, local leadership (political and customary) and the elderly farmers (over 70 years of age) provided the secondary data. Secondary information regarding culling of pigs due to CSF outbreak was also verified with records from the Department of Agriculture. The study was conducted from August to December 2009. Communities with many pig owning households were identified with the assistance of the National Department of Agriculture. The households with pigs were identified with the assistance of the local leadership and the snowballing technique was used to select participants who were willing to participate in the project. The snowballing method, however, has bias in that it may not truly represent the target population. Identifying the appropriate person to conduct the sampling, as well as locating the correct targets is time consuming and expensive. The key informants were interviewed to establish the pig production trends, factors affecting production levels and traits of economic importance, as a first step in designing a structured questionnaire. The questionnaires were administered in the vernacular *Xhosa* language. Farmers' wealth status was categorised during interviews with key informants and was based on number of livestock species. Any household owning more than five head of cattle or more than 20 head of small stock (sheep, goats and pigs) was considered as less resource-limited while the other category of less privileged people was considered as resource-limited.

The number of households interviewed in Elundini, Ngqushwa and Ntabankulu was 122, 102 and 64, respectively. Data were collected using structured questionnaires and included demographic data, pig rearing systems, number of pigs culled per household, perceptions of farmers on the severity of CSF and how the government should have controlled it. Additional data included compensation price for different classes of pigs and whether farmers received it, farmers' perceptions on whether the compensatory price was satisfactory and suggested compensation price. Changes of pig prices with disease outbreaks, government's effort in restocking, households experiencing pig mortality due to diseases, sending of dead pigs for post-mortem, incidences, impact and control of internal worms in pigs were also captured. Farmers were asked on their perception regarding the tolerance of their pigs to gastro-intestinal parasites. The households were also asked to give other diseases they are experiencing in their areas and how they treat against them. Direct observations were made to verify pig genotypes. The perceptions of the people on the need to conserve the local pig genetic resources were captured using a structured questionnaire.

3.2.3 Statistical analyses

The Generalised Linear Models (GLM) procedure of SAS (2006) was used to analyse the effects of farmers' socio-economic profiles, area of location (coastal and inland) and pig production systems (market- and subsistence-oriented) on the number of pigs culled. Pair-wise comparisons of the least square means for culled pigs were performed using the PDIFF option. Information regarding demographic data, production system, pig genotypes, farmer's perceptions on CSF incidences, impact and control of pig diseases was analysed using PROC FREQ of SAS (2006).

An ordinal logistic regression (PROC LOGISTIC) was used to estimate the probability of household experiencing pig diseases (SAS, 2006). The logit model fitted predictors such as area of location, pig production system (market- or subsistence-oriented), pig rearing system (free range or backyard), household size, pig housing, and head of household's demographic factors such as age, education level, employment status, marital status and place of residence (stays mainly at home or works and stays away from home). The logit model used was:

In $[P/1-P] = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3\ldots + \beta_tX_t + \varepsilon$

Where:

P = the probability of a household experiencing pig diseases;

$[P/1-P]$ = odds ratio, which referred to the odds of household experiencing pig diseases;

β_0 = intercept;

$\beta_1X_1\ldots\beta_tX_t$ = regression coefficients of predictors

ε = random residual error

When computed for each predictor ($\beta_1 ... \beta_t$), the odds ratio was interpreted as the proportion of households experiencing pig diseases versus those that did not experience them.

3.3 Results

3.3.1 Farmers' socio-economic profile

The socio-economic profiles of respondents in the Elundini, Ngqushwa and Ntabankulu Municipalities are shown in Table 3.1. Overall, about half of the interviewees were men, the other women across the three municipalities. Mean household size across all municipalities was 5.2 ± 4.63 (mean ± standard error) members. Most of the interviewees in Elundini, Ngqushwa and Ntabankulu municipalities were did not have a formal employment and survived on subsistence farming or social grants. The majority of respondents were thus resource-limited in the three municipalities while others were less resource-limited. There were more respondents with basic education (Grade 1-7) than secondary or tertiary education in the three municipalities. The majority of the interviewees in Elundini, Ngqushwa and Ntabankulu municipalities were Christians, while the remaining were African tradition worshippers. Most of the heads of households were resident on the farms in the three municipalities. In all three municipalities, most women over 60 years old were actively involved in pig rearing while men, boys and girls helped in the absence of women.

Most respondents across the production systems indicated that the youths were interested in pig rearing except a few who did not want to be associated with pigs because they are dirty.

Table 3.1: Socio-economic characteristics of respondents (%) in different locations

Socio-economic characteristic	**Elundini (SO) n = 122**	**Ngqushwa (MO) n = 102**	**Ntabankulu (SO) n = 64**
Male headed households	52	47	55
Married respondents	67	63	73
Women owning pigs	81	60	69
Unemployed respondents	79	77	80
Respondents with basic education (Grade 1-7)	50	55	47
Respondents that were Christians	88	84	70
Heads of households[1] living on the farm	70	85	65
Female pig keepers over 60 years of age	51	37	37
Youths reported as interested in pig rearing	66	89	79
Respondents who were resource-limited	69	75	84
Respondents raising pigs on the backyard	73	89	36

SO = subsistence-oriented production system, MO = market-oriented production system.

[1]The head of household was defined as the person who was taking care of the day to day management of the house. For example, if the father was staying away at work, the woman was considered as the head of the household.

Across all the municipalities, pigs were mostly owned by women. The majority of farmers were using backyard pig rearing system where the pigs were free roaming in the yard and the remainder were using the free range or scavenging pig rearing system (Table 3.1). About 86 % of the farmers reported that the major field crop they grew was maize, largely for household consumption and as supplementary feed for livestock. The other minor crops grown for consumption, in order of importance, were beans, vegetables, potatoes and pumpkins.

3.3.2 Farmer perceptions on classical swine fever outbreak

The impact of CSF and the perceptions of farmers about the disease are shown in Table 3.2. The majority of farmers in Elundini and Nqushwa Municipalities had their pigs culled due to CSF. There was, however, no culling of pigs in Ntabankulu Municipality. There were differences ($P < 0.05$) in the number of culled pigs per household in Elundini (4 ± 1.00), Ngqushwa (8 ± 1.76). There were few households in Ngqushwa (13 %) and Ntabankulu (10 %) municipalities that had no pigs during the CSF outbreak. Generally most farmers in the current study regarded CSF as a dangerous disease which reduce production and profit (Table 3.2).

Most farmers in all the municipalities suggested the need for vaccination in order to control the disease (Table 3.2). Few farmers supported the culling of pigs as a control measure in all municipalities (Table 3.2). There were more farmers in Ngqushwa Municipality than the other two municipalities who believed that housing pigs and educating people about CSF would help in controlling the disease. All the respondents confirmed that they were aware of the government’s compensation price of R2000 per breeding sow.

Table 3.2: Farmer perceptions (%) about classical swine fever disease outbreak

Pig production and disease attributes	Elundini (SO) n = 122	Ngqushwa (MO) n = 102	Ntabankulu (SO) n = 64
Respondents with culled pigs due to CSF	97	93	0
Respondents who hid their pigs from culling	17	22	27
Respondents who never saw controllers of CSF	17	9	16
Respondents who thought CSF was dangerous	60	88	67
Respondents who thought CSF reduces pig production	10	13	12
Respondents who thought CSF decreases pig price	28	86	55
Respondents who had no idea about CSF impact	29	0	21
Respondents who believed in vaccination against CSF	71	50	66
Respondents who believed housing controls CSF	7	22	11
Respondents advocating for educating people about CSF	2	28	10
Respondents who supported culling of pigs	14	0	10
Respondents who wanted compensation in pigs	50	0	38
Respondents who received monetary compensation	25	71	0
Respondents satisfied with compensation price	100	83	63
Respondents requesting a restocking programme	68	80	66
Respondents who wanted loans for restocking	0	36	20
Respondents who demanded better extension services	56	64	56

SO = subsistence-oriented production system, MO = market-oriented production system.

There were few respondents in Elundini and Ntabankulu Municipalities who wanted the government to compensate them with uninfected pigs instead of money (Table 3.2). Ngqushwa Municipality had the highest number of respondents who had been compensated for their culled pigs followed by Elundini Municipality (Table 3.2). Few farmers in Ngqushwa and Ntabankulu Municipalities wanted loans for pig projects. Most people across the three municipalities demanded better extension services from the government as part of the restocking efforts (Table 3.2).

3.3.3 Other disease challenges

The perceptions of respondents on the gastro-internal parasites and pneumonia challenges faced in different municipalities are shown in Table 3.3. There were few households across the municipalities who experienced piglet mortality due to diseases. There were few respondents in Ngqushwa Municipality who were experiencing gastro-intestinal parasites when compared to the other two municipalities. Generally, most farmers across the municipalities confirmed gasto-intestinal parasites have more effect on weight loss than either growth rates or death (Table 3.3). The majority of farmers in all municipalities mentioned that local pigs were tolerant to these parasites. There were more respondents in Ngqushwa Municipality who were using conventional drugs against gastro-intestinal parasites while the other two municipalities used more of traditional herbs for the same purpose (Table 3.3). Other minor diseases that were experienced by respondents in the three municipalities included mange and pneumonia (Table 3.3). Across the municipalities, most people were not sending their pigs for post-mortem.

Table 3.3: Respondents (%) experiencing other pig disease or parasites challenges in different locations

Pig production and disease attributes	**Elundini (SO) n = 122**	**Ngqushwa (MO) n = 102**	**Ntabankulu (SO) n = 64**
Respondents with disease caused piglet mortality	15	23	22
Respondents whose pigs have internal worms	28	12	44
Respondents confirming worms cause loss in pig weight	82	79	79
Respondents confirming worms cause poor growth rates	6	21	14
Respondents experiencing pig deaths from worms	6	0	3
Respondents who thought local pigs are worm tolerant	59	79	70
Respondents who use conventional drugs against worms	37	87	47
Respondents using traditional herbs to control worms	63	13	46
Respondents experiencing pig mange challenge	17	39	26
Respondents whose pigs were coughing or had fever	23	12	25
Respondents who send dead pigs for post-mortem	1	6	3

SO = subsistence-oriented production system, MO = market-oriented production system.

Causes of piglet mortlity, diseases incidences and level of internal worm infestation were based on farmer perceptions regarding symptoms shown by affected pigs.

3.3.4 Odds ratios for disease outbreak

The odds ratios of a household experiencing disease or parasite challenges were highest for subsistence-oriented production systems, followed by head of household staying away from the homestead, area of location, education level and age of head of household (Table 3.4). Subsistence-oriented production system was three times more likely to experience diseases than the market-oriented production system. The odds ratio of 2.783 showed that heads of households who were staying away from the farm had a higher likelihood of experiencing pig parasites and diseases challenges. The educated farmers were more likely to experience pig diseases and parasites than their uneducated counterparts. Pigs for households headed by young people were affected by parasites and diseases more than those led by old people (Table 3.4). Coastal areas were also more challenged by diseases than inland ones.

3.3.5 Prospects of restocking areas affected by CSF

On average 22 % of the farmers were resisting culling insisting that they were an important part of their livelihoods. Most people (92 %) mentioned that they were infuriated seeing government officials going around killing pigs. These farmers felt that the government was being inconsiderate by destroying their pigs without giving them immediate compensation to survive on. It was mainly piglets that were hid from government officials inside the houses while some tied mature pigs in the nearby bushes or mountain. All the farmers supported the idea of the government initiating a national restocking programme in the areas affected by CSF. It was surprising that after the culling exercise in 2005, pig ownership was fast spreading in the communal households at the time of the study. The only thing that was limiting some farmers venturing into pig production was shortage of breeding stock.

Table 3.4: Odds ratio estimates, lower and upper confidence interval (CI) of a household experiencing disease and parasite challenges

Disease and parasites challenge	Odds ratio	Lower CI	Upper CI
Area of location (inland vs coastal)	2.482	1.415	4.354
Pig rearing system (backyard vs free range)	0.766	0.408	1.437
Production system (MO vs SO)	3.026	1.593	5.747
Age of head of household (young vs old)	1.907	0.567	6.415
Education (uneducated vs educated)	2.202	1.186	4.089
Employment status (unemployed vs employed)	0.719	0.376	1.375
Residence of household head (at the farm vs away)	2.783	1.231	3.869
Household size (large vs small)	1.158	0.691	1.930
Pig housing (pigs not housed vs pigs housed)	0.485	0.230	0.824
Marital status (married vs not married)	0.989	0.775	1.280

MO = market-oriented production system, SO = subsistence-oriented production system.

The first category in each bracket was used used as a base level.

3.4 Discussion

Many people hid their pigs from government officials and refused to accept compensation price that was about four times their market value because their pigs were so important to them. Piglets are the ones which were hid indoors while mature pigs were tied in the nearby bushes or mountains. The findings suggest that the South African government does not understand their peoples' desires/aspirations and how they are controlled by market forces. The self-initiated restocking revealed the commitment of farmers in resuscitating their source of livelihoods, the majority of whom were unemployed. Women were more affected by the culling since they are the ones who rear more pigs than men for food and income generation (Chiduwa *et al*., 2008). Half of the women were heads of households which means it would be difficult for them to support their families without pigs. The fact that no culling was done by the government in Ntabankulu Municipality may be an indication that the disease did not spread to the communities where the survey was carried out. The continued upkeep of local pigs by the resource-limited communal farmers supports sustainable agricultural development (Drucker and Anderson, 2004). The majority of the youths were interested in helping with pig rearing implying pig production may continue into the future in communal areas. Youths might have enjoyed pig rearing because they were benefiting from the pork and cash through sales. In the restocking programme, it can be suggested to fund women because they were the major owners of pig as men were interested in large stock like cattle.

The majority of the farmers regarded CSF as dangerous since it reduced pig production and profit; this position is supported by previous reports (Widjojoatmodjo *et al*., 1999; SAPA 2005; FAO, 2009). For example, the South African government paid more than R200 million to compensate the more than 83 000 affected farmers (NAFU, 2007). The disease slowed down the development of the pig industry, reduced trade at the national and international levels and resulted in job losses (SAPA, 2005). The country lost potential revenue since it was banned from exporting pork up until it reached a CSF-free status. Farmers in Ngqushwa Municipality were affected more in terms of price drop since they were keeping more pigs for the market when compared to the other municipalities. Surprisingly most farmers did not support the government's approach of culling pigs even though they accepted that the disease was dangerous. This could be due to the fear of losing pigs as their source of livelihood through generation of income and provision of pork. Thus CSF reduced productivity and is a risk factor in food security (FAO, 2009).

The government's delay in compensating farmers may further explain the hiding of pigs by some farmers. The majority of the farmers in Ngqushwa Municipality had been compensated by the time of the study when compared to rural farmers in Elundini Municipality. According to the Department of Agriculture (2006), delays in compensation for rural farmers were orchestrated by lack of bank details for most of the rural farmers although efforts were made to pay them through the Post Office. Unless market-related compensation for pigs slaughtered is paid promptly, farmers are tempted to evade the control measures and, since movement control is seldom invincible, this can result in rapid spread of the CSF virus (Penrith and Thomson, 2004). Lack of cooperation from farmers made it difficult for the government officials to effectively control the CSF disease. The finding that some farmers in Ngqushwa Municipality were not satisfied with the compensatory price suggest that the government should pay them more than the market price for forced culling because it inconvenienced their business. Farmers in subsistence-oriented production systems might have appreciated compensation in the form of unifected pigs instead of money. It could be that farmers feared failure to secure breeding stock when permission to restock is granted. This finding further supports the fact that CSF causes loss of pig biodiversity. The concurrence with monetary compensation in Ngqushwa Municipality may be because farmers were enlightened that it would take time for them to be allowed to restock. As a market-oriented community, they might have wanted to unlock their money and invest it elsewhere.

The South African government was justified in its culling action since it is recommended to stamp out infected and in-contact pig herds with destruction of the carcasses as one of the traditional control measure to achieve eradication of CSF after an outbreak (Elbers *et al*., 1999; Garner *et al*. 2001; Mangen *et al*., 2002). Instead of culling, most farmers in Elundini and Ntabankulu Municipalities suggested that vaccination could have been a better option. The farmers' opinion was supported by some authors who reported that effective live-attenuated vaccines are available (Wehrle *et al*., 2007; Liu *et al*., 2009). Vaccination, however, is not allowed in the export market such as the European Union, since vaccinated and infected pigs are serologically indistinguishable (Widjojoatmodjo *et al*., 1999; Wehrle *et al*., 2007). The use of marker vaccines makes discrimination between vaccinated and infected animals possible (Widjojoatmodjo *et al*., 1999; Wehrle *et al*., 2007; Kaden *et al*., 2008). The acceptability of marker vaccines rests with trade partners. The use of these marker vaccines might not be an option for South Africa because they are costly to produce thus become expensive to the farmer. In addition, they are based on deoxyribonucleic acid (DNA) and proteins hence are not as efficacious as the live-attenuated vaccines (Greiser-Wilke and Moennig, 2004). The South African government currently depends on serological surveillance to control CSF; therefore vaccinating pigs as suggested by farmers would interfere with the epidemiological tool (Rossi *et al*., 2010). Farmers need to be educated on the government's reasons for the choice of the disease control programme so that they cooperate. The government of South Africa should conduct CSF awareness campaigns and workshops with all farmers in different production systems.

The finding that farmers in Ngqushwa Municipality believed in educating people about the disease and housing pigs as control measures may be due to their market-orientation which makes them stricter. NAFU (2007) reported that the spread of CSF in Eastern Cape Province of South Africa was mainly due to free ranging pigs. Farmers in Ntabankulu and Elundini Municipalities, however, indicated that they could not afford the government's recommended pig housing structure unless the government is to construct it for them. Most farmers in these municipalities were resource-limited and, hence, largely depend on government. The continued free ranging of pigs increases the chance of them mixing with infected wild pigs thereby compromising the CSF control effort (Penrith *et al*., 2011). Acutely infected pigs that are shedding large amounts of virus in their saliva, as well as lesser amounts in urine, faeces, ocular and nasal secretions, are a potent source of infection for other pigs (Penrith *et al*., 2011). The disease is also transmitted from pregnant sow to foetuses or from one farm to another through equipment, vehicles and people (Van Oirschot, 2004). After the CSF outbreak farmers in affected areas were prohibited from slaughtering any pigs at the abattoirs to stop the spread of the disease through the food chain. The South African government is currently using serological monitoring to control the CSF disease (Department of Agriculture, 2006).

Gastro-intestinal parasites, mange and pneumonia were some of the major challenges faced by farmers in all municipalities because communal farmers cannot afford to regularly buy conventional drugs. Farmers in Ngqushwa Municipality had a low internal worm challenge when compared to others because they dosed their pigs against internal worms with conventional drugs. Farmers' observations agrees with findings by Marufu *et al*. (2008), who reported that if untreated, internal worms cause loss of weight, reduced growth and death in pigs. Generally, all farmers considered local pigs to be tolerant to disease challenges and could survive well on treatment using traditional herbs. Across all Municipalities, the majority of farmers were not sending their pigs for post mortem which makes it difficult for the Department of Agriculture to quickly detect any disease outbreak especially in communal production systems. Delays in detecting outbreak of exogenous contagious diseases like CSF (Ruggli *et al*., 1996; Liu *et al*., 2009; Podgórska and Stadejek, 2010) will result in the virus travelling long distances affecting many pigs hence increased costs of controlling the disease (Edwards *et al*., 2000; Leifer *et al*., 2005; Rowlands *et al*., 2008).

The odds ratios for a household experiencing disease challenges were affected by demographic factors, area of location and production system as was also reported in cattle (Mapiye *et al*., 2009). An uneducated household head, permentantly resident at the farm was less likely to experience disease outbreaks because s/he is always available to better manage the pigs than educated counterparts who might be at work. Market-oriented production system was less likely to experience pig diseases because farmers have resources for vaccination and their pigs are confined in proper sties. The spread of diseases is high in free roaming pigs as was the case with the outbreak of CSF (Penrith *et al*., 2011). A young resident head of household has less risk because s/he may be more likely to comply with government's recommendations to control diseases like CSF such as confining the pigs. Young heads of households are energetic and this enables them to have better access to the needed resources. Coastal municipalities like Ngqushwa and Ntabankulu are more likely to experience disease outbreaks because of their hot humid conditions which harbour diseases (Rowlands *et al*., 2008; Jutla *et al*., 2010; Ortiz-Pelaez *et al*., 2010).

The majority of the farmers in Elundini and Ntabankulu Municipalities wanted the government to come up with a restocking programme in affected areas in order to restore the local pig biodiversity. Currently, the efforts from local municipalities are not capable of providing loans to all farmers who want to revive their piggery projects. Farmers requested the government to promote the production of Kolbroek, Windsnyer and their crosses with imported pigs because they are hardy and resistant to diseases as was reported by Halimani *et al*. (2010). Local pigs have low maintenance costs since they can utilise locally available feed resources, because of their small-frames they also need less nutrient for mantainance (Chimonyo *et al*., 2005). It could be important for the government to initiate local pig breeding centres to facilitate restocking and conservation of local pig biodiversity in communal production systems. The government can identify those areas in the Eastern Cape Province which were not affected by the disease and multiply the local pig genetic material. Currently few farmers can access LW pigs from Tsolo Agricultural College but these imported breeds cannot survive the harsh communal environment and they are costly to maintain.

Farmers in Ngqushwa Municipality wanted the government to avail loans which are not tied to cooperatives because they are capable of producing many pigs as individuals. These farmers being market-oriented already have pig structures and experience in pig rearing. Access to government loans and reliable market might help farmers restock; and boost pig production. The fact that majority of farmers wanted the government to provide better veterinary and extension services might imply they do not want to experience the devastating effects of diseases again. This will go a long way in supporting the conservation of threatened local pig genetic resources.

3.5 Conclusions

The odds ratios showed that resource-limited farmers in subsistence-oriented production system were more likely to experience pig diseases than their less resource-limited counterparts in market-oriented production system. Coastal areas were more likely to have disease outbreaks because of their hot humid conditions when compared to dry inland areas. Classical swine fever, however, had equally devastating effects once there is an outbreak in an area. More pigs were culled in market-oriented production system which was located on the coastal areas of Ngqushwa Municipality when compared to inland subsistence-oriented production system in Elundini Municipality. The culling of pigs affected pork availability, income generation and caused ecosystem disturbance in the crop-livestock both communal production systems. The same challenges were not witnessed in CSF-unaffected coastal area of Ntabankulu Municipality. Most farmers in market- and subsistence-oriented production systems regarded CSF as a dangerous disease to their source of livelihoods (pigs) and they wanted the prevention of any future outbreaks. To better understand the importance of local pigs to farmers' livelihoods under market- and subsistence-production systems; it is essential to investigate pigs' utilisation as farmers strive to recover from the devastating effects of CSF. Pig selection criteria and breeding practises should be investigated to advise policy-makers on restocking CSF-affected areas.

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CHAPTER 4: Utilisation of local pigs in subsistence- and market-oriented communal production systems in South Africa

(Submitted to *Tropical Animal Health and Production*)

Abstract

Local pigs are a source of livelihood, food security and economic emancipation of people in communal production systems. The objective of the study was therefore; to evaluate the utilisation of local pigs in market- and subsistence-oriented production systems that are both prevalent in improving people's welfare in South Africa. Data were collected from a total of 186 subsistence-oriented households, and 102 market-oriented households using interviews and direct observations. Most subsistence-oriented (93 %) and market-oriented rural households (82 %) kept local pigs such as Windsnyer, Kolbroek and non-descript crosses with imported pigs mainly for selling, consumption and investment. Ranked in order of importance, the major constraints faced by pig farmers in both production systems were diseases and parasites challenges, feed shortages, inbreeding problems and abortions. Market-oriented households ranked selection criteria of pig breeding stock in order of importance as based on growth rate, meat quality and litter size while in subsistence-oriented households selection was based on meat quality, growth rate and feed costs. The selection criteria for the subsistence-oriented communal production system focused on both productive and adaptive traits, while the market-oriented production system focused on productive traits. It was concluded that there is higher utilisation potential of local pigs in subsistence-oriented production system and crosses of local pigs with imported genotypes in market-oriented production system.

Key words: Pig genetic resources, Local pigs, Rural development, Selection criteria.

4.1 Introduction

Subsistence-oriented production system had higher risk of CSF outbreak than market-oriented production system (Chapter 3). It is not known how farmers are utilising local pigs as they try to restock different production systems found in communal areas and cope with the devastating effects of CSF outbreak. In Southern Africa, policy makers regard communal areas the same yet the objectives pursued by communities may differ. Lemke and Valle Zárate (2008) reported that smallholder pig production systems can be differentiated according to location, market access and production intensity. Communities that are located near urban areas are usually driven by the market demand for pork while areas far away from the towns raise pigs for subsistence or informal markets in the community (Lemke and Valle Zárate, 2008). The pig genotype preference for farmers near urban areas is likely to differ from those of poverty stricken rural farmers (Drucker and Anderson, 2004). As such, intervention measures to promote pig production in communal production systems should consider suitable genotypes that would assist farmers in different production systems to realise their production objectives.

Sustainable rural development programmes should integrate appropriate pig genotypes that can make use of the limited available local resources (Valle Zárate *et al*., 2003). For example, local pigs are well adapted to the backyard and scavenging production systems in developing countries (Pathiraja, 1987; Chimonyo and Dzama, 2007). Imported pigs are popular at first as they are brought in by development agents usually at no fee, but do not survive because they are not adapted to the harsh tropical environment. Farmers in communal production systems should be consulted to understand their production objectives and establish the selection criteria for pigs. This information is vital in understanding the multiple traits prioritised by these farmers when choosing the breeding stock (Roessler *et al*., 2008). Although local pigs are known to be hardy and resistant to diseases (Haresnape *et al*., 1987; Haresnape and Wilkinson, 1989; Zanga *et al*., 2003), their contribution to poverty alleviation in communal production systems is not fully understood. Selecting for disease resistance can make pig production cheaper for resource-limited communal farmers. Research should establish all the factors which affect household pig selection criteria and herd size to formulate policies that boost communal pig production and contribute to household food security.

Wealth is also disproportionately distributed among communal households with the market-oriented households being better off than the subsistence-oriented households. The level of wealth of the household significantly relates to the household's ability to cope with risks (Langyintuo and Mungoma, 2006), associated with pig production such as CSF. It is likely that the differences in the wealthy status and production objectives, rather than geographical location, might affect pig genotype preferences and pig herd size and, therefore, warrant investigation. As such, the sampling of farmers in this study was meant to represent market-oriented farmers in Ngqushwa Municipality and subsistence-oriented farmers in Ntabankulu and Elundini Municipalities. The goal of the study was to explore the utilisation of local pigs in rural development and inform policy on conserving pigs. The information may be useful for the restocking of local pigs in areas affected by CSF in South Africa. The objective of the study was to explore the utilisation of local pigs for rural development in subsistence- and market-oriented production systems of South Africa. The hypothesis that was tested was that the utilisation of local pigs in subsistence- and market-oriented production systems of South Africa is similar.

4.2 Materials and Methods

4.2.1 Study sites

The study was conducted in communal areas of Elundini (subsistence-oriented), Ntabankulu (subsistence-oriented) and Ngqushwa (market-oriented) municipalities in the Eastern Cape Province of South Africa. The details for the study sites are similar to what was described earlier in Section 3.2.1.

4.2.2 Data collection

The data collection procedures are as outlined earlier in Section 3.2.2. Data were collected using the structured questionnaire included demographic data, pig production levels (litter size, herd size, pre-weaning mortality) under backyard and free range rearing systems. Litter size at birth was defined as number born alive from the most recent litter and pre-weaning mortality was defined as proportion of piglets that died before weaning from the most recent litter. Other information collected included causes of piglet mortality, pig health management, breed preference and traits of economic importance, contribution of local pigs to food security and poverty alleviation, purposes and functions of pigs. Free ranging system was defined as a form of husbandry where pigs are not confined indoors during the day (sometimes includes night) but are allowed to roam freely in the community feeding on kitchen wastes, plant roots and fruits (Chimonyo *et al*., 2005). In backyard rearing systems pigs are kept inside the fenced yard and fed on kitchen wastes and even commercial feed though sparingly. The utilisation of local pigs for rural development was also investigated using a structured questionnaire to come up with a proper restocking programme in areas affected by CSF.

4.2.3 Statistical analyses

The Generalised Linear Models procedure of SAS (2006) was used to analyse for the effects of farmers' socio-economic profiles, pig production system (subsistence- and market-oriented) and pig feeding system (backyard and free ranging) on pig herd sizes, litter size at birth and pre-weaning mortality. Pair-wise comparisons of the least square means for litter size at birth and pre-weaning mortality were performed using the PDIFF option. The reasons for keeping pigs, causes of piglet mortality and reasons for pig genotype preferences were ranked using the Kruskal-Wallis test (NPAR1WAY procedure) (SAS, 2006).

Pig herd size of five and less than five were considered to be small, while herd sizes above five were regarded as large. An ordinal logistic regression (PROC LOGISTIC) was used to determine the probability of a household producing pigs for sale or income generation (SAS, 2006). The logit model fitted pig production system (market- and subsistence-oriented), pig rearing practice (free range and backyard), availability of housing structures for pigs, cattle and pig herd sizes, sheep and goats flock sizes) and socio-economic (gender, age, education, employment, wealth status, household size and whether the head of household was resident on the farm) factors. The logit model used was:

$$\text{In } [P/1-P] = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3\ldots + \beta_tX_t + \varepsilon$$

Where:

P = the probability of a household producing pigs for income generation;

[P/1−P] = odds ratio, which referred to the probability of household producing pigs for income generation;

β_0 = intercept;

$\beta_1X_1 \ldots \beta_tX_t$ = regression coefficients of variables;

ε = random residual error.

When computed for each predictor ($\beta_1 \ldots \beta_t$), the odds ratio was interpreted as the proportion of households producing pigs for income generation versus those that produced for subsistence.

4.3 Results

4.3.1 Farmers' socio-economic profiles

The socio-economic profiles of respondents in the market- and subsistence-oriented are similar to the description under Section 3.3.1. Activities carried out by women included feeding of pigs, penning, facilitated mating, health management, purchasing breeding stock and selling pigs. Men were involved in slaughtering and construction of housing for the pigs. Farmers across the production systems ranked cattle as the most important livestock species followed by sheep, goats, pigs, poultry and mules.

4.3.2 Pig production levels

In all the communal production systems, most of the respondents kept local pigs. In both the market-oriented and subsistence-oriented production systems, 12 % of the respondents kept non-descript crossbreds (have unknown proportion of mixed blood for LW, Landrace, Kolbroek or Windsnyer) while the rest kept local pigs. In the market-oriented production system some farmers had more than one genotype, with 15 % of the households keeping imported pigs such as the LW and the Landrace. The market-oriented production system had a higher mean household pig herd size when compared to the subsistence-oriented (Table 4.1). Youth (< 30 years of age) headed households had higher ($P < 0.05$) pig numbers (9.0 ± 2.61) than those headed by people over 60 years old (6.6 ± 2.35). Farmers with tertiary education also had large pig herd sizes (9.1 ± 2.69) than those with no formal education (6.9 ± 2.35). Resource-rich households had higher mean pig herd sizes of 8.1 ± 2.39 compared to 6.3 ± 2.34 for resource-limited households ($P < 0.05$).

Market-oriented production system generally had a higher ($P < 0.05$) number of breeding female pigs than the subsistence-oriented Elundini Municipality (Table 4.1). The number of breeding females was however, not different ($P > 0.05$) between Ngqushwa and Ntabankulu Municipalities. Gender of head of household, marital status, occupation, religion, production system and farmer's place of residence had no effect on total pig numbers or number of breeding females. Litter size was higher ($P < 0.05$) for Ngqushwa Municipality than the subsistence-oriented Elundini Munipality (Table 4.1). Ngqushwa Municipality however, had similar ($P > 0.05$) litter size with Ntabankulu Municipality. Pigs managed by married people had significantly larger litters than pigs managed by widows. Farmers with tertiary education owned larger ($P < 0.05$) litter sizes (11.9 ± 2.07) than those without formal education (9.0 ± 1.76). Pigs for employed respondents had a significantly large litter size (10.4 ± 1.77) than their non employed counterparts (8.5 ± 1.83). Wealth status also affected litter size with the resource-rich households; pigs attaining significantly higher litter size (10.3 ± 1.78) than resource-limited households (9.1 ± 1.76). Gender of head of household, religion and pig rearing system (backyard versus free range) had no effect on litter size.

Table 4.1: Household pig production levels (mean ± standard error) in subsistence- and market-oriented production systems

Production parameter	Elundini (subsistence-oriented)	Ngqushwa (market-oriented)	Ntabankulu (subsistence-oriented)
Total herd size	5.5 ± 2.33^{a}	8.2 ± 2.39^{b}	7.9 ± 2.59^{ab}
Breeding females	1.2 ± 0.83^{a}	2.0 ± 0.85^{ab}	2.0 ± 0.92^{b}
Litter size	8.4 ± 1.73^{a}	10.5 ± 1.79^{b}	10.3 ± 1.99^{ab}
Pre-weaning mortality	0.9 ± 0.84^{a}	1.7 ± 0.86^{b}	2.3 ± 1.04^{c}

^{abc}Within a row, values with different superscript letters differ ($P < 0.05$).

Pre-weaning mortality was higher (P < 0.05) for the subsistence-oriented Ntabankulu Municipality than the other two municipalities (Table 4.1). Herds managed by elderly people (> 45 years) had high pre-weaning mortality (1.6 ± 0.80) compared to those managed by youths (< 30 years) (1.6 ± 1.00). Gender of head of household, marital status, occupation, religion, wealthy status, farmer's place of residence and education level did not affect pre-weaning mortality.

4.3.3 Uses of pigs in rural development

Reasons for keeping pigs varied with the production system (Tables 4.2). Selling to raise income for the household was ranked as the most important reason for keeping pigs in market-oriented production systems while consumption was ranked high in subsistence-oriented production system. Raising pigs for subsistence was ranked as second in market-oriented production system while selling was ranked as second in subsistence-oriented production system. Respondents in subsistence-oriented production system ranked socio-cultural uses of pigs as third while savings and investment was more important in market-oriented production system. Farmers in both production systems considered pigs as important for provision of fat for use as cooking oil, softening leather ropes or mixing with other concoctions to chase away evil spirits. Farmers in all production systems mentioned that the local pigs are an integral part of the crop-livestock system because of their ability to utilise fibrous materials from crop residues and the provision of manure to fertilise crops in gardens.

The majority of farmers in Elundini (81 %), Ntabankulu (65 %) were selling pigs in the community while those in Ngqushwa (96 %) were selling to abattoirs, butcheries and/or supermarkets. The market values of a breeding sow in Elundini, Ngqushwa and Ntabankulu

Table 4.2: Reasons for keeping pigs in communal areas as ranked by subsistence- and market-oriented respondents

Reason	Rank (mean rank)[a]		
	Subsistence-oriented (n = 186)	**Market-oriented (n = 102)**	**Sig**
Selling for income generation	2 (1.62)	1 (1.27)	*
Subsistence	1 (1.30)	2 (1.77)	*
Savings and investment	4 (2.95)	3 (2.80)	ns
Manure	6 (3.36)	4 (3.74)	ns
Provision of Fat	5 (3.27)	5 (3.76)	*
Socio-cultural	3 (2.00)	7 (4.50)	*
Family pride/status	7 (3.38)	6 (3.92)	ns

[1]The lower the rank of the reason, the greater the importance.

ns = not significantly different, *Significant difference ($P < 0.05$).

Sig = significance level.

Municipalities were USD105.00 ± 11.67, USD158.00 ± 15.41 and USD46.00 ± 3.82 respectively (exchange rate 1USD = R7) (South African Reserve Bank, 2010). Farmers were also selling piglets to raise income in Elundini (USD75.00 ± 5.99), Ngqushwa (USD14.30 ± 2.57) and Ntabankulu (USD8.60 ± 1.02). The probability of household producing pigs for income generation were highest for provision of pig housing followed by age of head of household, pig rearing system, cattle herd size, and sheep flock size and employment (Table 4.3). The probability of selling pigs for income generation was high for housed pigs than those that were not housed (odds ratio 7.524). An odds ratio of 2.224 indicates that younger people (< 45 years old) were likely to sell their pigs for income generation than old people (> 45 years). Households practising backyard rearing system were also likely to sell pigs for income generation than those using the free ranging system. Farmers with small herds of sheep and cattle were likely to keep pigs for income generation. All farmers mentioned that pigs were important in poverty alleviation or improving their welfare through income generation and provision of pork.

4.3.4 Pig breeding practices

Despite the culling that took place in many communities, many respondents (64 %) across all production systems purchased their breeding stock from other farmers while others selected within their herds. However, most of the interviewees across production systems (66 %) borrowed boars and they would give a piglet when their sow farrowed. For those with boars, 80 % of them said that one boar was serving less than 5 sows they were struggling to secure breeding females after the CSF outbreak. Only 64 % of the farmers across production systems mentioned that they control mating with those practicing free range rearing finding it most difficult.

Table 4.3: Odds ratio estimates, lower and upper confidence interval (CI) of a household producing pigs for income generation

Pig herd size	Odds ratio	Lower CI	Upper CI
Pig rearing system (free range vs backyard)	2.164	0.966	4.850
Cattle herd size (large vs small)	1.869	0.755	4.627
Goats flock size (large vs small)	0.873	0.397	1.920
Sheep flock size (large vs small)	1.681	0.576	4.909
Age of the head of household (old vs young)	2.224	0.599	8.257
Education (uneducated vs educated)	1.026	0.453	2.321
Employment (employed vs unemployed)	1.541	0.598	3.972
Residence of household head (at the farm vs away)	0.750	0.373	1.511
Household size (large vs small)	0.767	0.373	1.576
Wealth status (resource-rich vs resource-limited)	0.261	0.090	0.754
Pig housing (pigs not housed vs pigs housed)	7.524	2.112	26.809
Marital status (not married vs married)	1.174	0.774	1.780

The first category in each bracket represents the base level.

Methods used by farmers in all the production systems to control mating and reduce inbreeding were separation of boars and sows (25 %), early culling of the boar (9 %), borrowing a boar (16 %), castration (19 %), exchange unrelated boars permanently (9 %) and the rest (22 %) exchanged boars with other farmers after two years of use. Early culling of the boar was perceived to stop it from mating its offspring. Weaning period ranged between three to seven months. Gilts reached puberty after about eight months, farrowed once per year.

4.3.5 Constraints to pig production

Respondents in the market-oriented Ngqushwa Municipality ranked reduced mature size over generations as the major problem associated with inbreeding while the subsistence-oriented Ntabankulu Municipality ranked declining litter size first and Elundini Municipality ranked piglets born dead first (Table 4.4). Thirty two percent of the respondents said that reproduction is seasonal with 26 % of these saying the sows farrow in the cold dry season, 65 % in raining season and 9 % anytime. There were few case of dystocia (3.2 %) reported in the production systems. However, the cases of abortion were 11.3 % across the research areas. The other problem faced by farmers was piglet mortality. Factors that contributed to piglet mortality across production systems were ranked in order of importance as being crushing by older pigs, cold stress, dystocia, cannibalism due to hunger, diseases and predation by dogs. Approximately 24 % of the farmers across the production systems monitored farrowing. Most interviewees in Elundini and Ngqushwa Municipalities penned their pigs at night when compared to those in Ntabankulu Municipality (Table 4.5). About 72 % of the farmers across the production systems had basic housing structures completely made up of zinc iron sheets and some respondents (36 %) separated piglets from older pigs.

Table 4.4: Challenges associated with inbreeding as ranked by respondents in different communal production systems

Problem	Elundini (subsistence-oriented)	Ngqushwa (market-oriented)	Ntabankulu (subsistence-oriented)	Sig
Reduced mature size over generations	2 (1.62)	1 (1.52)	3 (1.67)	ns
Declining litter size	4 (1.90)	4 (2.18)	1 (1.21)	**
Weak piglets	3 (1.66)	2 (1.63)	2 (1.27)	ns
Piglets born dead	1 (1.50)	3 (2.00)	4 (2.00)	ns

**Significant difference amongst production systems at $P \leq 0.01$.

ns = no significant difference amongst production systems.

[1]The lower the rank of the challenge, the more important it is.

Table 4.5: Challenges, pig production practices and perceptions of respondents (%) in market- and subsistence-oriented production systems

Socio-economic characteristic	Elundini (SO) n = 122	Ngqushwa (MO) n = 102	Ntabankulu (SO) n = 64
Respondents keeping local pigs	89	82	97
Respondents using backyard rearing system	73	89	36
Respondents whose rearing system varied seasonally	18	34	16
Farmers experiencing feed shortage	75	92	79
Respondents housing their pigs at night	68	90	32
Respondents who confirmed climate change	62	93	95
Respondents experiencing gastro-intestinal parasites	28	44	23
Respondents who borrow breeding boars	65	66	26
Respondents who support conservation of local pigs	86	88	92
Respondents who thought local pigs are heat tolerant	93	90	87

MO = market-oriented, SO = subsistence-oriented

The majority of farmers across all the production systems (94 %) did not keep pig records. Overall, farmers mentioned the need to address some of these breeding challenges in order to make the national pig restocking programme successful.

Eighty-two percent of the interviewees across production systems experienced feed shortage and they prefered pigs which could forage to cut down on feed cost. Most of the interviewees in Elundini and Ngqushwa Municipalities kept their pigs under backyard rearing system while most interviewees in Ntabankulu Municipality reported that their pigs were under free ranging (Table 4.5). Few respondents practising free ranging system in winter enclosed their pigs during the summer season.

Most respondents acknowledged that the climate has changed to very hot and dry weather conditions (Table 4.5). Climate change affected cropping (83 %), availability of foraging material (16 %), water (17 %) and has contributed to death of pigs due to starvation and heat stress (14 %) (farmers selected more than one effect). About 52 % of the farmers across the production systems had no means of adapting to climate change. The majority of farmers thought that the local black pigs could be tolerant to heat and should be conserved (Table 4.5).

4.3.6 Traits selected for breeding pigs

Respondents in subsistence-oriented production system mainly selected pig breeding stock for meat quality, growth rate and low feed cost, while those in market-oriented production system selected for growth rate, meat quality and large litter size (Table 4.6).

Table 4.6: Ranks of traits used for selecting pig breeding stock in consumption- and market-oriented production systems

Traits	**Rank (mean rank)[a]**			
	Elundini (subsistence-oriented) (n = 122)	**Ngqushwa (market-oriented) (n = 102)**	**Ntabankulu (subsistence-oriented) (n = 64)**	**Sig**
Growth rate	2 (2.58)	1 (2.23)	2 (2.29)	ns
Litter size	4 (3.72)	3 (3.19)	3 (4.43)	*
Meat quality	1 (2.16)	2 (2.67)	1 (2.27)	*
Low feed cost	3 (3.57)	5 (4.66)	4 (4.36)	*
Parasite/disease resistance	5 (4.21)	4 (4.21)	6 (4.95)	*
Foraging ability	7 (5.14)	9 (6.12)	5 (4.83)	**
Mothering ability	6 (4.96)	6 (5.26)	9 (6.50)	**
Temperament	10 (6.22)	8 (5.95)	8 (6.34)	ns
Heat tolerance	8 (5.57)	7 (5.53)	7 (5.66)	ns
Body conformation	9 (6.09)	10 (6.23)	10 (7.25)	*

[1]The lower the rank of the attribute, the greater is its importance.

Sig = significance level.

*Mean ranks of attributes in different municipalities are significantly different at $P \leq 0.05$.

**Mean ranks of attributes in different municipalities are significantly different at $P \leq 0.01$.

ns = not significantly different.

Across all the production systems, 86 % of the respondents preferred the local pig genotype over the imported ones based on their own perception of eating pork quality attributes (farmers chose more than one attribute) such as tenderness (34 %), fatness (30 %), taste (89 %), colour (12 %) and juiciness (18 %). Litter size is the other productive attribute which was highly ranked by farmers especially in Ngqushwa and Ntabankulu Municipalities. Body conformation and temperament were lowly ranked by all municipalities (Table 4.6).

4.4 Discussion

The finding that pig production was mainly the duty of women concurs with researchers in different countries (Ajala *et al*., 2007; Lemke *et al*., 2007; Chiduwa *et al*., 2008). According to Chiduwa *et al*. (2008), women are responsible for cooking and have access to kitchen left-overs to feed pigs. It was also reported that women help each other in pig husbandry in exchange for a piglet, thereby spreading ownership within the gender as was reported by Chiduwa *et al*. (2008).

The promotion of pig production by women is a developmental tool in communal production systems. The young and educated people had better husbandry skills than the old people. This was supported by the fact pigs owned by old people (> 60 years) experienced high pre-weaning mortality than those owned by the youths (< 30 years). According to Ajala *et al*. (2007), the youths can easily bear the risk of accepting new innovations aimed at improving pig production. The young people can also face the challenges of pig rearing given the demand of integrating both crop and livestock enterprises especially for labour. The involvement of youths in pig production reduces unemployment and the problems associated with it. Farmers who reside at the farm have more time to better manage their pigs and minimise production losses.

The observed high number of rural farmers keeping local pigs supports the view that they are a source of livelihood since they can thrive under low input production systems. Local pigs can forage and survive on the fibrous diets commonly found in communal production systems (Lemke *et al*., 2006; Chimonyo *et al*., 2010). This explains the use of either backyard or free range rearing systems by many communal pig producers. Farmers keep pigs in traditional free ranging systems as a means of risk management in terms of feed availability. Farmers reported feed as the major limiting factor in increasing pig herd size. The free ranging feed resource base was also reported to limit the number of pigs that can exist in the community under free ranging conditions in many countries (Mashatise *et al*., 2005; Ajala *et al*., 2007; Lemke *et al*., 2007). The observed change of pig rearing system from free ranging to backyard during the rainy season concurs with what was reported by Chiduwa *et al*. (2008) in Zimbabwe. This is done so that the pigs do not damage crops which are also a source of livelihood for farmers in these crop-livestock mixed production systems. Lekule and Kyvsgaard (2003) reported that free range rearing systems were associated with high levels of infectious diseases and low productivity although this was not confirmed in this study. In this regard, the South African government is advocating for the confinement of pigs as a way to contain the spread of CSF.

Most communal farmers lack sufficient resources to adequately support pig production hence they experienced constraints such as poor housing, abortion, high pre-weaning mortality, inbreeding problems and low productivity. Farmers who were residing at the farm were unlikely to have their pigs experiencing diseases because of good managenent levels. Many farmers reported local pigs to be tolerant to gastro-intestinal parasites. This might be an advantage for the majority of pig owners who are in remote areas with limited access to veterinary services and cannot afford to buy commercial drugs. The high odds ratio of 3.026 (Chapter 3) for disease and parasites prevalence in subsistence-oriented production system might suggest that pig farmers in these areas experience high pre-weaning mortality, which might indicate lack of resources to deal with these challenges (Langyintuo and Mungoma, 2006). However, since pure local pigs are resistant to diseases and parasites, producers using cross-breeds (local x exotic) are the ones likely to experience this problem. According to Dial *et al*. (2002), diseases might cause abortion, reduction of farrowing rates, litter size at birth and weaning, birth weight and viability of piglets, sow's milk yield and litter weight gain. Farmers in market-oriented production system are assisted to manage the rare disease outbreaks by the veterinary expertise from the National Department of Agriculture.

The finding that all the farmers in market- and subsistence-oriented production systems faced feed shortages might be because pigs competed with humans for maize grain. Lemke *et al*. (2006) reported that deficient feeding of the lactating sow prolongs the weaning-to-oestrus interval, hence the observed once a year farrowing. Feed shortage and the CSF outbreak might explain the observed low herd sizes since farmers could not afford to sustain large pig herd sizes. Farmers controlled herd size by selling excess piglets or consuming the mature pigs. The odds ratio for selling pigs showed that farmers with pig housing were seven times likely to own large pig herd and sell some of them when compared to those without pig housing. Pig housing protects them from harsh weather conditions such as heat and cold stress which minimises pre-weaning mortalities. Poor and muddy housing also predisposes the piglets to diseases and increases deaths due to cold stress. Thus, local pigs still need good husbandry practices despite being hardy and resistant to many environmental challenges. This might also reinforce the need to separate piglets from older pigs to minimise the crushing of piglets.

The study showed that many farmers in the market-oriented production system appreciated the dangers associated with mating related pigs hence they tried to control mating by separating females and males, castration, early culling and exchange of boars. Despite taking all these measures, farmers faced many problems associated with inbreeding because they continue to use related pigs. The challenge became bigger with the outbreak of CSF which made it difficult to secure replacement boars (NAFU, 2007). The subsistence-oriented farmers practising free range rearing system could not control mating in winter except in summer when they switch to backyard production. The borrowing and exchange of boars is too localised and at the end all the pigs in the community will be related. Reluctance to sell the best breeding stock amongst farmers in both production systems might have resulted in the use of foundation stock with poor breeding qualities. Consequently, farmers would start to experience pigs with stunted growth; small litter size, weak piglets or they are born dead (Halimani *et al*., 2010). It is recommended that farmers buy breeding boars from very far-away communities and keep them for a very short period in the breeding herd to minimise chances of inbreeding. Farmers need better extension services so that they improve on pig breeding which in turn positively affects their potential profits.

Most farmers considered the keeping of boars as uneconomical because the numbers of sows kept in many households was small. Relying on hired boars for breeding sows affects breeding plans when the boar is not available and this contributed to poor farrowing index (Wabacha *et al*., 2004; Huynh *et al*., 2007). Indiscriminate crossbreeding of local pigs with imported pigs should be discouraged because it dilutes the ability of local pigs to resist disease challenges hence threatening the genetic resource. In addition, the local pigs survive better under resource-limited conditions hence the South African government should not contribute to threatening them by promoting imported pigs during the restocking programme. The government is recommended to spearhead the set up of a national research centre responsible for the conservation of pure local pigs that will be bred and sold to rural farmers for sustainable rural development.

In view of the multiple challenges faced under communal production systems, it seems farmers have tried to align their pig functions and breeding objectives. Market-oriented production system ranked selling to raise income followed by consumption as the major functions of pigs as also reported elsewhere (Mashatise *et al*., 2005; Ajala *et al*., 2007). Wealth is disproportionately distributed among communal households. The level of wealth of the household is significantly related to the household's ability to cope with risks (Langyintuo and Mungoma, 2006), associated with pig production such as CSF and feed shortages. The market-oriented households also valued pigs as a form of savings or investment because they are profit minded when compared to the socio-cultural uses selected for by the subsistence-oriented households. This could explain why Ngqushwa Municipality mainly selected pigs for productive traits, such as growth rate and litter size so that they can have a high turnover since they are market-oriented. This also might explain the observed large litter size in market-oriented production system when compared to subsistence-oriented production system.

The market-orientation of Ngqushwa Municipality might have contributed to the observed high household pig herd size for income generation. The market-oriented production system also had better extension services and initiatives to restock after the outbreak of CSF. These findings concur with the argument that pigs are better managed when they make a significant contribution to production and income than when saving is the major function (Bennison *et al*., 1997). Thus the market-oriented production system had a large pig herd when compared to the subsistence-oriented production system. The low average parity (< 3) across production systems might have contributed to low herd productivity since pigs perform best in their mid parities (3-5) (English *et al*., 1988). The educated and employed people had high pig numbers because they have the financial resources and technical know-how to support pig production.

The finding that both subsistence- and market-oriented farmers selected for growth rate might suggest that they also want the crossbreds which grow fast but at the same time can survive under their low input production systems. Crossbreeding is only beneficial when well planned. Indiscriminate cross-breeding, replacement of local pigs with imported pigs and lack of clearly defined policies on conservation of local genotypes threaten their continued existence (Halimani *et al*., 2010) and chance to contribute to development of future breeds. Farmers also selected pigs for mothering ability as another productive trait linked to ensuring large litter size at weaning. Even the pricing of the pig breeding females in market-oriented Ngqushwa Municipality was the highest (USD158.00) for the production systems because the farmers are business minded. However, it is not clear why all the production systems poorly ranked body conformation yet it's important when selecting for high meat yield hence more profits. People selected pigs for meat quality (eating quality) since subsistence was also ranked as the second major important function of pigs. Meat from pigs raised under free ranging rearing system has a better taste than imported ones because it is lean (Lemke and Valle Zárate, 2008). Although local pigs were selected for meat quality, they tend to be discriminated against at the commercial market because of their colour and short carcasses, which cannot be prepared into specialised meat portions (Chimonyo *et al*., 2010). Farmers also selected pigs for adaptive traits such as disease or parasites resistance and heat tolerance. Selection for disease or parasites resistance is important since farmers cannot afford to purchase commercial drugs.

Subsistence-oriented respondents selected pigs for adaptive traits such as foraging ability because it limits feed costs while this trait was not be very important for the market-oriented respondents who could afford even to buy commercial feed to supplement their pigs. The finding that a majority of the respondents acknowledged effects of climate change might imply the need to identify genotypes that can better survive the harsh climatic conditions. Many people in market-oriented and subsistence-oriented communal production systems were finding it difficult to adapt to climate change and this might suggest the need for the policy makers in Southern Africa to develop coping strategies. One of these strategies would be to promote a pig genotypes that are heat tolerant hence have higher chances of survival under communal production systems where pigs hardly have shelter. Bull *et al*. (1997) reported that pigs are poor at thermoregulation and climate change might pose a challenge especially to those few farmers who might want to use imported pigs. The adaptability of the local pig genetic resources to harsh tropical environment might be the reason farmers wanted the South African government to promote them during the national restocking programme in the Eastern Cape Province.

4.5 Conclusions

Local pigs were mainly used for income generation in the market-oriented production system while they are used for consumption in the subsistence-oriented production system. Local pigs have the potential to produce good litter size and attain lower pre-weaning mortalities under market-oriented production system than subsistence-oriented production system. The selection criteria for the subsistence-oriented households focused mainly on adaptive traits such as foraging ability, heat tolerance, diseases and parasites resistance. Market-oriented focused on productive traits such as large litter size at birth and fast growth. To recommend the appropriate pig genotypes for restocking communal production systems, there is need to identify those pig genotypes that are likely to survive heat stress from direct sun burn since most farmers cannot afford to build proper pig houses. Information on other traits of economic importance is fairly available except for climate change adaptation. The change of climate to hot conditions poses a direct challenge on pig production because of their poor thermoregulation.

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CHAPTER 5: Diurnal heat-related physiological and behavioural responses in Large White and South African local gilts

(Submitted to *Journal of Arid Environments*)

Abstract

The study compares the heat tolerance of South African local pigs with that of imported LW pigs in the hot-wet season in South Africa. Rectal temperature, skin surface temperature, breathing rates and heart rate were recorded three times every other day (0800 h, 1200 h, 1600 h) for a period of 105 days. Twelve 6-week old gilts of each genotype were used. There were no differences ($P > 0.05$) in breathing rate and rectal temperature between the pig genotypes. Skin surface temperatures and heart rates were higher ($P < 0.05$) for the LW pigs than local pigs at all times of the day. Overall, all the tested physiological parameters increased ($P < 0.05$) with time of the day reaching a peak during mid-day before decreasing at 1600 h. The frequency and duration of wallowing, sprawling in slurry and lying in prostrate posture were higher in LW than local pigs. Local pigs had higher ($P < 0.05$) values for hair length, final hair density and fat thickness than the LW pigs. These findings suggest that local pigs could be more tolerant to heat stress than LW pigs.

Key words: Breathing rate, Heart rate, Rectal temperature, Skin surface temperature, Wallowing.

5.1 Introduction

The majority of farmers in communal areas who are subsistence-oriented selected breeding pigs based on adaptive traits such as heat tolerance when compared to few market-oriented farmers who focused on productive traits (Chapter 4). To minimise the adverse effects of heat, the prospects of global warming from climate change (Smith *et al*., 2007; Scholtz, 2009; Thornton *et al*., 2009) calls for identification of these heat tolerant pig genotypes (Gregory, 2010). Pig genotypes that can withstand high temperatures would be valuable under harsh conditions likely to prevail in the future. While local pigs of Southern Africa are thought to be heat tolerant (Nengomasha, 1997), mechanisms behind this superiority have not been adequately researched to increase the pigs' value. The Windsnyer is the most common local genotype in South Africa. The known merits about local pig genotypes are not taken advantage of to benefit the resource-limited farmers who rely on them for their livelihood. This is particularly important in communal production systems of Southern Africa where local pigs are mainly kept without proper housing and they are exposed to direct sun while free ranging for feed. Information on the genetics of adaptation will assist policy makers in recommending appropriate pig genotypes to restock communal production systems of South Africa. Although imported pigs have high reproductive performance (Chimonyo *et al*., 2008), they are less likely to survive the harsh environmental conditions prevailing in communal production systems.

Pig skin has no functional sweat glands; therefore, instead of sweating they use behavioural thermoregulation to cool themselves (Huynh, 2005; Zumbach *et al*., 2008). To increase heat dissipation, they increase contact with a cooler surface (floor or mud) and sprawling out (Bull *et al*., 1997). Increased respiration, or panting, increases air flow and evaporation of water from the lungs, and hence releases additional heat (McGlone, 1999). Heat loss from the skin is also affected by thicknesses of skin and subcutaneous fat, hair colour, number of hairs per unit area, diameter of the hairs and angle of the hairs to the skin (McGlone, 1999). Information on pig physiological behaviour during exposure to environmental stress is limited but could be measured by variations in breathing rate (BR), rectal temperature (RT), heart rate (HR) and skin surface temperature (SST) as done with other livestock species (Svotwa *et al*., 2007; McManus *et al*., 2009; Mirkena *et al*., 2010). It is hypothesised that these behavioural and physiological mechanisms could explain the differences in thermoregulatory capacity of local compared to imported pig genotypes.

The majority of studies on the effects of heat stress in pigs have utilised constant temperatures set at different levels (Patience *et al*., 2005), yet, heat stress under commercial conditions varies diurnally. The most common index used to evaluate stressful climatic conditions for livestock is the temperature humidity index (THI), calculated from dry bulb and wet bulb temperature (Jones and Stallings, 1999). Little is known about heat tolerance mechanisms of Southern African local pigs. The evidence is anecdotal and there have not been any studies verifying the mechanisms responsible for this capacity. An understanding of heat tolerance mechanisms can assist in designing appropriate housing and to indicate adverse heat stress levels. The findings of the study can help increase the value of local pig genotypes by including them in future cross-breeding programmes with imported pigs for heat tolerance. The objective of this study was to compare the heat tolerance of South African local and LW gilts under hot-wet conditions which was the hottest season in the Eastern Cape Province, South Africa. It was hypothesised that South African local pigs and LW pigs have similar heat tolerance mechanisms.

5.2 Materials and Methods

5.2.1 Study site

The study was conducted at Fort Cox College of Agriculture and Forestry farm in the False Thorn grassland in the Eastern Cape Province of South Africa (27˚ 01′ E and 32˚ 46′ S). The climate is semi-arid with average annual rainfall of 480 mm. Rain falls predominantly in the summer months (November-April) with June and July being the driest months. The area experience very cold temperatures during the winter months with occasional snowfalls. The mean annual temperature of the farm is 18.7 ˚C.

5.2.2 Meteorological measurements

The hot-wet and hot-dry seasons have been described as thermally stressful to pigs (Asala *et al.*, 2010) and were worth investigating to recommend genotypes which could withstand the adverse effects. The current study focused on the hot-wet season because it is the hottest in the Eastern Cape Province of South Africa. Temperature and relative humidity were recorded daily at 1 h intervals during the study period between October 2010 and January 2011 using a temperature and humidity data logger (MT668 Major Tech Pvt Ltd, South Africa). Wet (T_w) and dry bulb (T_d) temperatures were recorded after every other day in the morning (0800 h), mid-day (1200 h) and late afternoon (1600 h) using a wet and dry bulb thermometer. This management practice avoided interfering grossly with pigs' welfare in feeding. The wet and dry bulb temperature readings were used to calculate THI for different times for the study period. The formula used was:

$THI = 0.72\ (T_w + T_d) + 40.6$ (WMO, 1989).

5.2.3 Pigs and their management

The experiment was managed following procedures approved by the University of Fort Hare Ethics Committee. Twelve 6-week-old gilts from each of the local and LW pigs were used. The average weight of the local and LW pigs at weaning was 7.4 ± 0.59 kg and 9.91 ± 0.59 kg, respectively. The LW pigs were obtained from Fort Cox College of Agriculture and Forestry, while the local pigs were obtained from the surrounding communities. To ensure that the local pigs were pure, farmers were asked about the breeding background of their pigs and phenotypic characteristics were also observed. Local pigs are narrow-bodied, long-nosed and razor-backed. Gilts were targeted because they are the ones used in large numbers as replacement stock in breeding programmes. No more than three piglets were randomly selected from individual litters.

At weaning and once a month thereafter, the pigs were dosed against internal parasites using Ivomec® (ivermectin) (Virbac, Republic of South Africa). The pigs were sprayed fortnightly with Triatix® (Amitraz) (Coopers, South Africa) against ectoparasites. No selection for heat tolerance was done by the farmers although they would want such animals. Each pig was an experimental unit. The pigs were identified and housed individually in a 3 x 2 m concrete floored and zinc-roofed pen. The walls of each pen were 1.5 m high and were representative of the housing structures in communal production systems of South Africa. All pigs were fed commercial feed composed of maize grain, soya bean meal and vitamin mineral premixes (Monti Feeds Pvt Ltd, East London, South Africa). Pigs were allowed to adapt to the feed for 7 days post-weaning. The pigs were fed *ad libitum*. From days 35 to 56, the pigs were fed on a pig weaner meal (180 g crude protein (CP)/kg, 13 MJ ME/kg DM). Pig grower meal (160 g CP/kg, 13.7 MJ ME/kg DM) was offered from day 57 till day 105. Clean tap water was always available in the pig sties from nipple drinkers. The pens were cleaned daily and pigs were fed individually.

5.2.4 Physiological responses

To measure physiological responses, each pig was confined in a 1.3 x 0.5 x 0.8 m metal cage with minimum restraint. The cage had steel bars on its sides and lockable doors on both ends. The pigs were handled three times a day for two weeks before the experiment began for them to get used to people and measurement routine. Rectal temperature (RT), skin surface temperature (SST), heart rate (HR) and breathing rate (BR) were taken at the same time at 0800 h, 1200 h and 1600 h every other day for the study period. The SST was measured after the natural drying of the skin of those pigs that had immersed themselves in water or slurry.

Breathing rate was taken first when the pig was at the resting phase that is, either sleeping or standing without any activity such as eating. Morning and afternoon breathing rates (breaths per minute) (bpm) were measured by visual observation of the flank movement for 60 seconds (Huynh, 2005).

Rectal temperature was measured by inserting a clinical digital thermometer (DT-KO1A, HѲMED™, China) into the rectum of the pigs for 60 seconds. An infrared thermometer (T611, Top Tronic, Taiwan) was used to measure SST as suggested by Patience *et al*. (2005). Skin surface temperature was taken for each pig from a distance of 15 cm without the instrument coming into contact with the animal body. The back SST measurement was taken from the spine just above the tail, which is the most exposed surface of the pig. The belly temperature was taken at the naval position. The SST was then taken as the average of the measurements taken from the back and belly of the pig. Skin surface temperature was measured at the same time as respiratory rate, breathing rate and heart rate for all experimental pigs. All measurements were taken in about 1.5 minutes per pig with the help of 4 trained personnel taking readings for different parameters. The HR for the pigs was determined by counting the number of heart beats per minute using a stethoscope. The stethoscope was placed on the left side chest of the pig in order to pick up the heart beats.

5.2.5 Pig behavioural changes

The pigs were monitored by visual observation for sprawling in their slurry and immersing themselves in drinking water which was in a 1 x 0.3 x 0.3 m concrete water trough in each pen. The frequencies for each activity were recorded for each genotype on the same days the physiological measurements were taken. The duration and behaviours of the pigs during immersion in water troughs were also recorded. The number of times and duration of prostrate sleeping postures of pigs were also recorded during heat stress. The times when pigs started sprawling in their slurry, immersing themselves in water troughs and lying in prostrate posture were noted. The THI values at the times when pigs were becoming uncomfortable due to heat stress were recorded.

5.2.6 Hair, fat and skin measurements

At the beginning and end of the study period, all the pigs had their hair shaved using a razor blade on the same small part of the hind leg in order to determine hair length and density (g/cm^2). Ten long hair strands were collected from each pig, their length measured (mm) using a calipers and averaged. At slaughter, each carcass was then cut cross-sectionally at the last rib up to and across the spinal cord to measure backfat thickness. Backfat and skin thicknesses were individually measured using a pair of vernier callipers at 75 mm (K7.5) from the mid line.

5.2.7 Statistical analysis

The effect of pig genotype, day, time of the day and their interactions on SST, RT, HR and BR was analysed using repeated measures analysis of variance (PROC GLM) of SAS (2006). The effect of day was used as a repeated measure. The following model was used:

$Y_{ijk} = \mu + G_i + T_j + G_i \times T_j + e_{ijk}$

Where: Y_{ijk} = the response variable (SST, RT, HR and BR);

μ = the overall mean;

G_i = the effect of i^{th} genotype (i = LW, Local);

T_j = the effect of j^{th} THI (j = THI at 0800 h, 1200h and 1600 h);

$G_i \times T_j$ = the effect of interaction of pig genotype and THI;

e_{ijk} = the residual error.

A similar model was used to analyse the effect of pig genotype on number of times and duration per day for behavioural activities (wallowing, sprawling in slurry and lying in prostrate posture). Data was, however, first transformed using $\log_{10}$ to normalise it.

The effect of pig genotype on skin thickness, fat thickness, hair density and hair length was analysed using PROC GLM of SAS (2006). The following model was used:

$Y_{ij} = \mu + G_i + e_{ij}$

Where: Y_{ij} = the response variable (skin thickness, fat thickness, hair density, hair length);

μ = the overall mean;

B_i = the effect of i^{th} genotype (i = LW, Local);

e_{ijk} = the residual error.

For pair-wise comparison of means for all the models, the PDIFF procedure of SAS (2006) was used. The Pearson's product moment correlations were computed to relate RT, SST, HR and BR for each genotype to changing diurnal THI.

5.3 Results

5.3.1 Meteorological measurements and pig behaviour

The mean hourly temperatures and relative humidity for the three-month study period are shown in Table 5.1. Mean temperatures were rising from 0600 h to reach a peak of 25.9 ± 0.36 (˚C) (mean ± standard error) at 1300 h and began to decrease up to 1800 h. Relative humidity was high at 0600 h (89.9 %) and decreased as temperature rose to reach a minimum of 61.7 ± 1.2 % at 1300 h. From 1400 h up to 1800 h, the relative humidity increased while temperature decreased (Table 5.1). THI was lowest in the morning (70.1 ± 0.25) and highest during mid day (74.8 ± 0.25). The 1600 h reading showed that THI decreased (73.5 ± 0.25) after the mid-day elevation. The highest THI, recorded at mid-day during the study period, was 85.3.

Large White pigs had higher ($P < 0.05$) frequency and duration of wallowing, sprawling in slurry and taking (lying in) a prostrate position (Table 5.2). Local pigs (76.2 ± 0.13) took this position at a higher ($P < 0.05$) THI than LW pigs (73.5 ± 0.14). After this they became uncomfortable and started sprawling in dung or immersing themselves in water (Table 5.2). After immersing themselves in water, both pig genotypes would remain in the water trough in a dog sitting stance.

Table 5.1: Mean hourly temperatures and relative humidity (± standard error of mean) for the 105 days study period

Time	**Temperature (˚C)**	**Relative humidity (%)**
0600 h	16.8	89.9
0700 h	18.0	86.9
0800 h	19.5	81.6
0900 h	20.9	77.2
1000 h	22.3	72.2
1100 h	23.8	67.9
1200 h	25.1	63.8
1300 h	25.9	61.7
1400 h	25.7	62.5
1500 h	25.0	64.9
1600 h	24.0	67.7
1700 h	22.7	71.0
1800 h	21.9	73.3
SEM	0.36	1.20

Table 5.2: Least square means (± standard error) for heat stress behavioural parameters of Large White and local pigs for the 105 days study period

Behavioural parameter	Number of times/day	Starting time	Duration (minutes/day)
Wallowing			
Large White	6.0 ± 2.10[a]	1200 h	15.1 ± 2.04[a]
Local	3.1 ± 1.03[b]	1300 h	8.3 ± 1.12[b]
Sprawling in slurry			
Large White	12.4 ± 3.13[a]	1000 h	20.0 ± 3.07[a]
Local	7.1 ± 1.41[b]	1100 h	15.1 ± 2.13[b]
Sleeping (prostrate posture)			
Large White	4.0 ± 1.02[a]	1300 h	70.6 ± 5.33[a]
Local	3.0 ± 1.11[b]	1300 h	60.9 ± 4.50[b]

[ab]Within a column and within a parameter, means with different superscript letters differ ($P < 0.05$).

From 1300 h to around 1430 h, the LW pigs stopped eating and sprawled on the floor in a prostrate posture. The local pigs spent a shorter time ($P < 0.05$) sprawling in a prostrate position.

5.3.2 Physiological measurements

There was no genotype and time interaction effect on all physiological parameters. There were no differences in the average RT for local and LW pigs at different THIs (Table 5.3). The peak RT (40.5 ˚C) was the same in local and LW pigs. Temperature humidity index affected RT ($P < 0.05$) for both pig genotypes, with the lowest readings at 0800 h and highest readings at 1200 h.

Temperature humidity index affected ($P < 0.05$) SST with the highest reading being recorded during mid-day. Large White pigs had higher ($P < 0.05$) HR at all THIs when compared to the local pigs. In both pig genotypes, HR was highest at mid-day when THI was at the peak. There were no differences ($P > 0.05$) in the average BR for the local and LW pigs for the whole study period (Table 5.3). However, BR continued to increase with time of day in both genotypes such that the highest rate was at 1600 h. There was a positive correlation ($P < 0.01$) between THI and, SST, HR and BR for both genotypes (Tables 5.4). In the LW pigs, THI was highly (positively) correlated with BR while it had the strongest positive correlation with SST in local pigs (Table 5.4). There was no correlation between THI and RT for the two genotypes (Table 5.4).

5.3.3 Hair, skin and fat measurements

Local pigs had a thicker backfat when compared to the LW pigs (Table 5.5). There was no difference in skin thickness, initial hair length and initial hair density for both genotypes.

Table 5.3: Least square means (± standard error) of local and Large White pigs for RT, SST, HR and BR at different THI and time of the day for the 105 days study period

	THI		
	70.1 ± 0.25	74.8 ± 0.25	73.5 ± 0.25
	Time		
Physiological parameters	0800 h	1200 h	1600 h
Rectal temperature (˚C)			
Local	39.5 ± 0.68^{a2}	40.5 ± 0.68^{a1}	39.1 ± 0.82^{a2}
Large White	39.1 ± 0.68^{a2}	39.2 ± 0.68^{a2}	40.5 ± 0.81^{a1}
Skin surface temperature (˚C)			
Local	31.7 ± 0.32^{b2}	33.5 ± 0.32^{b1}	33.1 ± 0.38^{b1}
Large White	33.6 ± 0.32^{a3}	35.1 ± 0.32^{a1}	34.0 ± 0.38^{a2}
Heart rate (beats per minute)			
Local	148.8 ± 1.47^{b3}	159.1 ± 1.47^{b1}	155.8 ± 1.75^{b2}
Large White	152.2 ± 1.47^{a3}	167.0 ± 1.47^{a1}	158.5 ± 1.75^{a2}
Breathing rate (breaths per minute)			
Local	44.6 ± 1.08^{a3}	54.1 ± 1.08^{a2}	57.5 ± 1.28^{a1}
Large White	43.3 ± 1.08^{a3}	54.2 ± 1.08^{a2}	57.5 ± 1.08^{a1}

^{ab}Within a column for each parameter, means with different superscripts differ ($P < 0.05$). ^{123}Within a row, means with a common superscript are not different ($P > 0.05$).

Table 5.4: Correlations between THI and physiological parameters for the local and Large White pigs over the 105 days study period

Physiological parameter	**Large White**	**Local**
RT	-0.02	0.03
SST	0.35*	0.62*
HR	0.30*	0.21*
BR	0.36*	0.33*

*Correlation coefficient significant ($P < 0.01$).

Table 5.5: Least square means (± standard error) for hair length, hair density, skin thickness and fat thickness for local and Large White pigs

Parameter	**Local**	**Large White**
Fat thickness at 20 wk (mm)	21.3 ± 1.03[a]	17.6 ± 1.03[b]
Skin thickness at 20 wk (mm)	3.1 ± 0.23[a]	3.1 ± 0.23[a]
Initial hair length at 8 wk (mm)	26.2 ± 1.58[a]	23.1 ± 1.58[a]
Final hair length at 20 wk (mm)	29.8 ± 1.26[a]	26.1 ± 1.26[b]
Initial hair density at 8 wk (g/cm^2)	0.05 ± 0.01[a]	0.02 ± 0.01[b]
Final hair density at 20 wk (g/cm^2)	0.07 ± 0.03[a]	0.04 ± 0.03[b]

[a,b]Within a row, means with a common superscript are not different (*P* > 0.05)

Local pigs had longer final hairs ($P < 0.05$) than the LW pigs (Table 5.5). Hair density was lower ($P < 0.05$) for the LW pigs than local pigs (Table 5.5).

5.4 Discussion

The upper limit of the relative humidity, which fluctuated between 61 and 90 %, was above the upper limit of the established normal values of 45 to 75 % for the imported pigs (Agricultural Research Council, 2006). The upper limit of relative humidity at mid-day was stressful especially to LW pigs. This was confirmed by LW pigs stopping feeding at THI of 73.5 ± 0.14. The THI at which LW pigs became uncomfortable (based on behavioural mechanisms) in this study was lower than the one reported by Silanikove (2000) and Gaughan *et al*. (2001). The THI at which local pigs became uncomfortable was higher than that for LW pigs. This suggests that local pigs tolerate heat better than the LW pigs although their zone of discomfort was also falling within the same (75-78) THI range reported by Silanikove (2000). Temperature humidity index of less than 70 is considered comfortable while that of 75 is at the alert stage of possible heat stress (Dubey and Gnanasekar, 2008). The recorded highest THI for this study fell within the very dangerous zone of above 84 (Lucas *et al*., 2000). The local pigs are, therefore, likely to survive and perform better under direct sunburn prevalent in communal free range production systems.

The higher frequency of wallowing, sprawling out and lying prostrate by LW compared to local pigs confirms the inherent inability of LW to tolerate heat stress. It has been reported, (Svotwa *et al*., 2007) that when inherent heat tolerance mechanisms fail to reduce heat stress, animals resort to behavioral mechanisms to dissipate heat. Generally, the LW pigs were employing the behavioural thermoregulatory mechanisms earlier than the local pigs probably because they are more susceptible to heat stress. The finding that LW were spending more time sleeping in a prostrate posture, sprawling in slurry and wallowing might suggest that they were struggling to lower the temperature to a comfort zone through evaporative cooling. The results support the finding by Huynh (2005) that imported pigs struggle to regulate temperature under the hot tropical environments. The fact that local pigs spend less time trying to regulate temperature through behavioural mechanisms might suggest that they have other superior thermoregulatory mechanisms. Productivity in LW pigs could be reduced when they stop feeding and spend more time trying to cool down although this was not assessed in this study. Renaudeau *et al*. (2008) reported that daily feed intake declined under hot humid conditions because of the limited ability of the pigs to dissipate excess heat. This may imply the need to intervene by spraying water on pigs to minimise the adverse effects of heat stress. The prospects of climate change are likely to worsen the stressful environment especially for imported LW pigs because temperatures are going to rise (Scholtz, 2009).

There were no differences in RT for the LW and local pigs probably due to the fact that RT is an indicator of core body temperature that does not vary much because of thermoregulatory control at the hypothalamic level (Hahn, 1990). Rectal temperature is a delayed indicator of heat stress tolerance only responding at temperatures above 27 ˚C or THI above 80 (Silanikove, 2000; Lorschy, 2005). If RT starts increasing it is a sign that the heat stress coping mechanisms are failing and the pig will rapidly succumb to heat stroke (Silanikove, 2000; Huynh *et al*., 2005), and hence has to be evacuated to a cooler place. In the current study, the average THIs were below 80 hence the observed little variation in RT. The observed RT values were slightly above the established normal range of 39 ± 1 ˚C (Lorschy, 2005; Asala *et al*., 2010). The current findings agree with Renaudeau *et al*. (2007) who reported no differences in RT for local Caribbean Creole and LW pigs. In both pig genotypes, RT rose with the rise in THI. The rise in RT can be also considered as a part of the mechanism of the pig to maintain a temperature gradient between core and skin temperature (Renaudeau *et al*., 2008). Rectal temperature is affected by other factors, such as metabolic heat generation and body activity rather than just THI (Svotwa *et al*., 2007). The production of metabolic heat is in turn affected by the energy content of the consumed feed (West, 1993). In the current study, pigs were fed the same diet. These findings suggest that LW and local pigs respond similarly in terms of RT.

The observed higher SST for LW pigs might suggest that they are more prone to heat stress than the local pigs. In this study, it is not clear why local pigs had lower SST despite being black, which is expected to absorb heat. It could be that black colour absorbs and emits a lot of heat compared to white colour (Hotep, 2009). The thick fat layer, long hairs and high hair density as was the case in local pigs, causes insulation hence minimising heat loss (Silanikove, 2000). The fatter local pigs were expected to be less able to handle hot conditions, yet it was not the case in this study. However, there is need to confirm if backfat thickness is representative of fat distribution across the body. It is possible that local pigs may release heat from their bodies through thermoregulatory windows arising from uneven distribution of subcutaneous fat. This therefore calls for a better understanding of the underlying physiological processes that control heat tolerance in the local genotypes. In particular, measurements of blood metabolites which indicate the actual level of stress in each genotype could be done. Additional studies can focus on heat tolerance of crossbreds for local and imported genotypes. The change in SST with time of day for both genotypes could be attributed to radiation falling on the skin of the pigs. Renaudeau *et al*. (2007) reported that a variation in SST under heat stress conditions could be a result of an increase of blood volume in skin blood vessels to promote sensible heat loss. There is paucity of information on change of SST with ambient temperature in growing pigs (Renaudeau *et al*., 2007). A rise in SST above the environment can also promote net outflow of longwave radiation from the skin of pigs (Gates, 1980). Thus LW pigs maintained a steep temperature gradient towards the environment in order to achieve both sensible and radiative heat loss. The rise in SST of the pig indicates a shift from heat production or conservation to dissipation and insulation reduction as reported by Svotwa *et al*. (2007) in beef cattle.

Large White pigs had higher HR than local pigs probably because they were trying to pump more blood to the peripheral tissues to dissipate excess heat. The results might suggest that the local pigs are more heat tolerant than LW because they were not struggling to dissipate excess heat. However, the morning HR in the current study was far above the normal of 90 bpm reported by Patience *et al*. (2005). Differences in climatic conditions under which experiments were carried might have affected HR with pigs in hot areas experiencing higher HR. Handling of pigs by people might have increased HR and future studies should attempt to use HR monitors (electronically). Patience *et al*. (2005) reported HR of 117 in heat stressed pigs at 1900 h. Heart rate reached a peak at mid-day before decreasing in both genotypes indicating that it was affected by THI. The increase in HR is part of biothermal mechanisms initiated to counteract the detrimental effects of high body temperature. Curtis (1983) reported that higher blood flow through the body shell is associated with increased body heat loss.

In the current study, it was anticipated to have higher SST on the skin of black local pigs because black fur absorbs heat. This might be the reason for the high correlation between THI and SST for local pigs. The structure and colour of hairs is likely to affect the flow of energy across the skin. Sensible heat flow was reported as higher at the base of black coat than either brown or white cattle (Silanikove, 2000). The local pig had lower SST despite being black suggesting it was better at dissipating heat than LW pigs. There is a limit to which SST can rise to maintain the gradient needed for efficient heat loss. In the event of the continued rise in environmental temperatures, a negative gradient towards the core of the body develops leading to net heat gain as reported in other animal species (Svotwa *et al*., 2007). In the current study, the mid-day temperatures were high hence causing a slight rise in core body temperatures.

The observed breathing rates for both pig genotypes were above the normal rates from mid-day. There were days in the current study when BR was above 180 bpm in LW pigs and this could be considered as extreme (Lorschy, 2005). Breathing rate is the first indicator of heat stress and can be affected by temperatures as low as 21.3 ˚C (Lorschy, 2005) or a THI of 73 (Silanikove, 2000). Normal breathing rate of pigs ranges from 15-30 breaths per minute (Silanikove, 2000) and BR above 40 indicate pigs are at risk of heat stress (Newsham Choice Genetics, 2009). On the contrary, Lorschy (2005) reported 50 breaths per minute as comfortable for pigs. In this study, both pig genotypes increased BR from mid-day maybe to achieve regulatory evaporative heat loss from the lungs. Kamada and Notsuki (1987) reported BR to be a good indicator for the latent heat loss and were important when the gradient between SST and ambient temperature was small (Renaudeau *et al*., 2007). The continued increase in BR as the day progressed was an indication of heat stress during the hot season. Although BR was more correlated with THI in both genotypes, it is not clear why it continued to rise even after THI decreased. This might suggest the presence of a lag phase between the THI decrease and the actual reduction in BR. The correlations between BR and THI for both pig genotypes were, however, too weak to be relied on. The findings indicate that the tropical environment is stressful to pigs in hot-wet season.

5.5 Conclusions

Large White pigs had higher heart rate and skin surface temperatures than local pigs. In addition, LW pigs had higher frequency per day and longer duration of wallowing, sprawling in their urine and sleeping in a prostrate posture than local pigs. It was concluded that local pigs had superior heat tolerance mechanisms than LW pigs. To better understand the impact of diurnal heat-related stress, the growth performance of each genotype need to be understood. Such studies can generate useful information which allows farmers to assess potential loss in production due to heat stress.

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CHAPTER 6: Effects of diurnal heat-related stress on growth performance of Large White and South African local gilts

(Submitted to *Animal*)

Abstract

Due to climate change, the predicted rise in ambient temperatures in Southern Africa has a huge impact on the availability of feed and water for livestock, especially the intensively managed species in semi-arid areas. The objective of the study was to establish the effects of diurnal heat-related stress on growth performance of South African local pigs and Large White (LW) pigs. Twelve six-week old gilts of each genotype were used in a completely randomised design. The Pearson's product moment correlation coefficient between temperature and feed conversion ratio (FCR) for LW pigs was strongly positive (r = 0.50; $P < 0.001$) unlike the weak one for local pigs (r = 0.20; $P < 0.05$). Regression analysis showed that there was a quadratic relationship between temperature and average feed intake per metabolic body weight for both pig genotypes. However, the regression coefficients were higher for LW ($P < 0.001$) than local pigs ($P < 0.001$). There was also a quadratic relationship between temperature and average daily gain for both pig genotypes although the regression coefficients were higher for LW ($P < 0.01$) than local pigs ($P < 0.01$). There was a positive linear relationship between temperature and feed conversion ratio for LW pigs ($P < 0.001$) and quadratic relationship for local pigs ($P < 0.01$). It was concluded that at high ambient temperatures, performance of local pigs were less compromised than for LW pigs. Slow-growing local pigs could, therefore, be more suitable for production where ambient temperatures are high.

Key words: Adaptation, Body weight gain, Climate change, Feed intake, Feed conversion ratio, Heat stress.

6.1 Introduction

Local pigs had superior heat tolerance over LW pigs in terms of lower heart rate, skin surface temperature, frequency and duration behavioural heat loss activities such as wallowing, and sprawling in slurry (Chapter 5). It is not known how the growth performance of these two pig genotypes is affected by the diurnal heat-related stress. This information is required in the designing and development of outdoor pig production systems that enhance pig welfare.The main challenge faced by outdoor pig production systems is the inability to manipulate temperatures towards the pigs' requirements for optimum production. Apart from providing shade and sprinkling water during hot periods, priority should also be given to the identification of appropriate pig genotypes. Characterisation of the slow-growing local pigs that are adapted to free-range extensive production systems could be worthwhile, as this also aids stakeholders in accurately estimating their economic value. These values are crucial in designing sustainable restocking and conservation programmes for the local pigs.

Feed costs are the major determinants of economic efficiency in a pig production enterprise (Klindt *et al*., 1999; Dube *et al*., 2011). Slow-growing local pigs of Southern Africa have high propensity to deposit body fat and low feed requirements, making them suitable for the low-input production systems (Chimonyo and Dzama, 2007). St-Pierre and co-workers (2003) highlighted that feed intake and feed conversion efficiency depends on environmental temperatures, yet this information is not available for pig genotypes of Southern Africa. In Chapter 3 and 4, farmers in a semi-arid communal production system indicated that climate has changed to hot conditions and the imported pigs promoted by government based on their productive traits are unlikely to thrive under the harsh environmental conditions.

There is dearth of information regarding the adaptation or growth performance of pig genotypes under high temperatures. It is hypothesised that maximum daily temperatures have the greatest negative impact on pig performance than other whether elements. With prospects of climate change to hot conditions in Southern Africa (Scholtz, 2009), livestock production is going to be affected due to limited water, feed and increased outbreak of diseases (Gregory, 2010). At high temperatures, pigs need water to cool down, yet, with global warming; this resource is likely to be in short supply. There is need to identify adapted pig genotypes so minimise climate change effects on pig production.

Hot conditions also increase bush encroachment and favours fast growing plants that are rich in fibre. Adaptation to these poor quality roughages prevailing in communal production systems limit the dependence of local pigs on grain which is mostly imported in developing countries (Chimonyo *et al*., 2005). Pig genotypes adapted to high temperatures are, therefore, likely to survive even under high temperatures, and, thus, suitable for the future. Documentation of the effects of heat stress on pig performance assists in decision-making on potential inclusion of local pigs in commercial outdoor production systems. The findings from the study could be used in designing crossbreeding programs that exploits genotype complementarity and heterosis. The ability of local pigs of Southern Africa to withstand high temperatures is not yet explained. Largely due to convenience of experimentation and controlled studies, there is abundance of literature on the performance of pigs under controlled temperatures (Patience *et al*., 2005; Huynh *et al*., 2005; Renaudeau *et al*., 2008). Few articles even report on temperatures beyond 35 ˚C. Diurnal variations in temperature are largely ignored. As such, studies based on random environmental changes are difficult to plan. Though difficult to replicate or repeat such studies, such experiments reflect how the prevailing ambient temperatures influence pig production. The objective of the current study was to establish the effects of diurnal heat-related stress on the growth performance of LW and local pigs of Southern Africa. The hypothesis tested was that high temperatures (beyond the thermo-neutral zone) have a similar impact on the growth performance of LW and local pigs.

6.2 Materials and Methods

6.2.1 Study site

The description of the study site is the same as outlined in Section 5.2.1.

6.2.2 Meteorological measurements

The daily temperatures are given in Section 5.2.2.

6.2.3 Pigs and their management

The description of pigs and their management is outlined in Section 5.2.3.

6.2.4 Pig performance measurements

Feed was weighed and added into the troughs such that the feed was available at all times. Feed refusals were collected daily at 0700 h. The difference between the feed that was offered and refusals was considered as the average daily feed intake (ADFI) (g/d) for each pig in an individual pen. Pigs were weighed weekly using a battery operated platform scale (Ruddweigh Pty Ltd, Guyra, Australia). Changes in body weight were used to estimate the average daily gain (ADG). Feed conversion ratio (FCR) was calculated as the amount of feed consumed to gain 1 kg of body weight. The FCR for each treatment was computed by the following equation:

FCR = F/(Wf-Wo), where

F = the weight of feed consumed to pigs during the week;

Wo = the live weight of pigs at the beginning of the week; and

Wf = the live weight of pigs at the end of the week.

6.2.5 Statistical analyses

The ADFI values were expressed per kg metabolic body weight ($M^{0.75}$). The generalized linear model (GLM) procedures of SAS (2006) were used to determine the effects of pig genotype, time of sampling (weeks) and their interaction on ADFI, ADG, FCR and weekly body weight. The model used was:

$Y_{ijk} = \mu + G_i + T_j + G_i \times T_j + e_{ijk}$

Where Y_{ijk} = response variable (ADFI, ADG, FCR, body weight);

μ = overall population mean;

G_i = effect of i^{th} pig genotype (i = LW, Local);

T_j = effect of j^{th} week (j = weeks 1,...15);

$G_i \times T_j$ = interaction between pig genotype and time (weeks);

e_{ijk} = the residual error.

The effect of pig genotype on the final body weight, overall ADFI, ADG and FCR were analysed using the following model of PROC GLM of SAS (2006):

$Y_{ijk} = \mu + G_i + W_j + e_{ijk}$

Where Y_{ij} = the response variable (final body weight, overall ADFI, ADG and FCR);

μ = overall population mean;

G_i = effect of the i^{th} pig genotype (i = LW, Local);

W_j = effect of initial weight (covariate);

e_{ijk} = the residual error.

Initial weight of the pigs in each pen was used as a covariate. Separation of means was done using PDIFF procedure of SAS (2006). Pearson's product moment correlations between average maximum daily temperatures for the one-week periods and performance parameters such as ADFI, ADG and FCR were also calculated for each pig genotype. A regression analysis for temperature versus ADFI, ADG and FCR were also carried out for each pig genotype using PROC RSREG of SAS (2006).

6.4 Results

Overall, mean maximum daily temperatures increased with over time, being above 25 ˚C for the greater part of the study period (Figure 6.1). There were differences in mean weekly temperatures ($P < 0.05$) across the study period with the highest temperatures in the 9^{th} week and the lowest in the 2^{nd} week (Figure 6.1). In Week 9, when mean temperatures were highest (34.5 ± 2.16 ˚C), ADFI decreased rapidly for both pig genotypes (Figure 6.2).

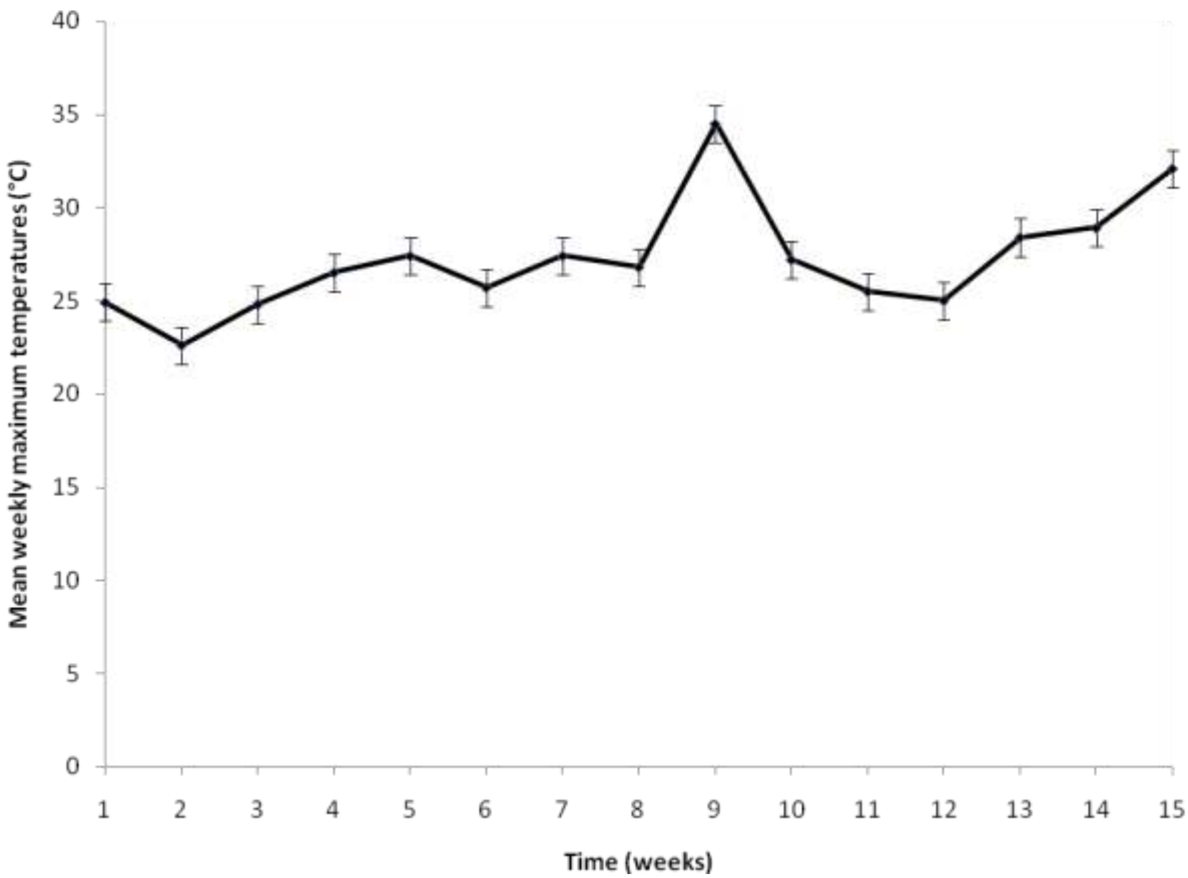

Figure 6.1: Mean (± standard error) of daily maximum temperatures for one-week periods

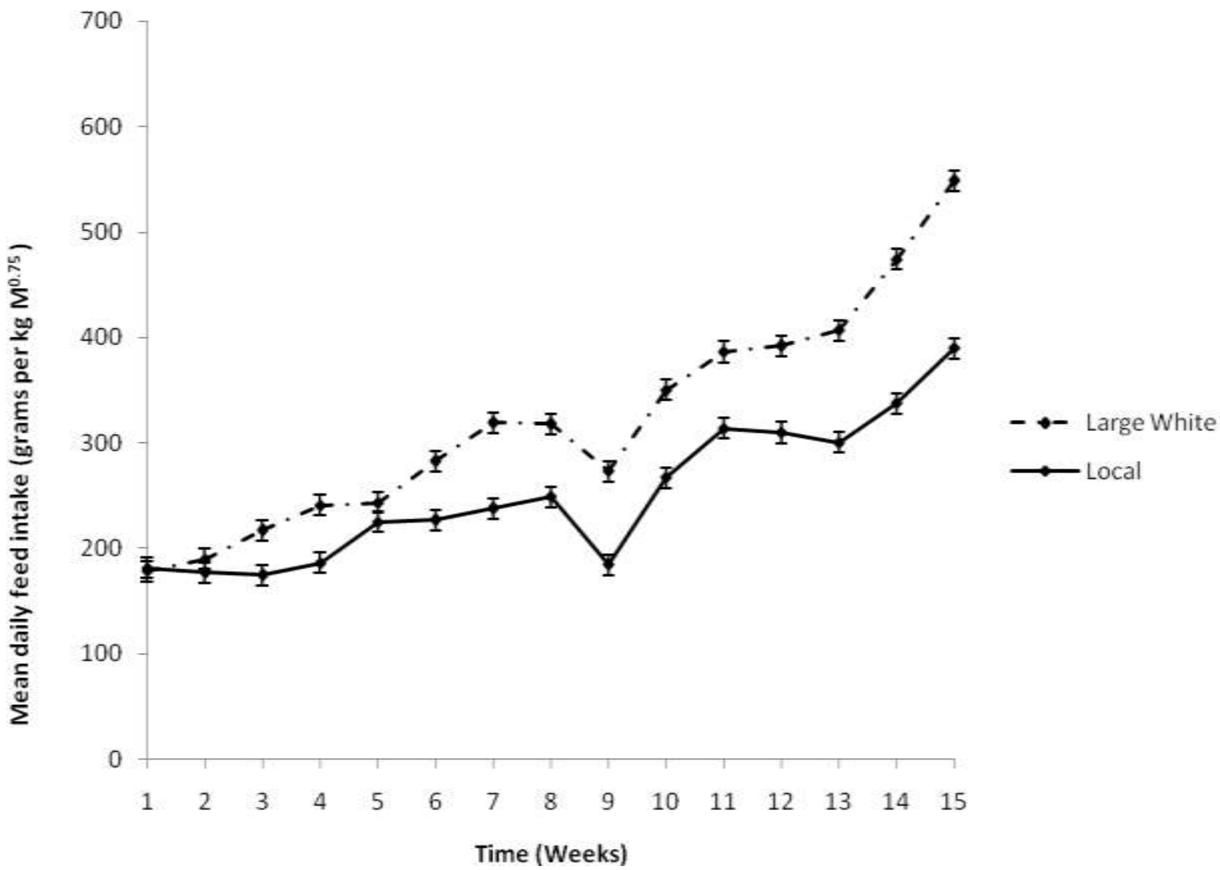

Figure 6.2: Mean (± standard error) daily feed intake per kilogram metabolic body weight for the Large White and local pigs over the study period

The ADFI increased with time in both pig genotypes. Large White pigs had a sharp rise in ADFI while the ADFI for local pigs was constant for the first three weeks post adaptation period. The weekly body weights for both LW and local pigs increased with little variation over the study period (Figure 6.3). On week fifteen post-weaning, the local pigs showed a steady body weight gain while LW was still on the sharp increase. The final body weight of the LW pigs was higher than for local pigs (Table 6.1). The correlation between temperature and ADFI was positive and high for LW pigs than local pigs (Table 6.2). The regression coefficients for temperature on ADFI for LW pigs were higher than for local pigs (Table 6.3). The regression model predicted that ADFI starts decreasing at 32 ˚C in both pig genotypes. There was a quadratic relationship between temperature and ADFI for both pig genotypes (Table 6.3). However, the regression coefficients for ADFI were higher for LW ($P < 0.001$) than local pigs ($P < 0.001$).

In Week 9, when temperatures were highest, ADG decreased by 56% from 723.8 ± 49.00 g to 317.9 ± 49.00 g for LW pigs (Figure 6.4). The effects were, however, less ($P < 0.05$) for local pigs having decreased by 50 % from 452.4 ± 49.00 g to 226.2 ± 49.00 g in Week 9. In week 12, when temperatures decreased to 25 ± 2.16 ˚C, ADG increased to 904.8 ± 49.00 g for LW and 511.9 ± 49.00 g for local pigs (Figure 6.4). Despite being seriously affected by heat stress, LW pigs had higher ADG at the end of the experimental period than local pigs (Table 6.1). The Pearson's product moment correlation coefficient between temperature and ADG was negative and higher for LW than local pigs (Table 6.2). There was a quadratic relationship between temperature and ADG for both pig genotypes although the regression coefficients were negative and higher for LW ($P < 0.01$) than local pigs ($P < 0.01$) (Table 6.3).

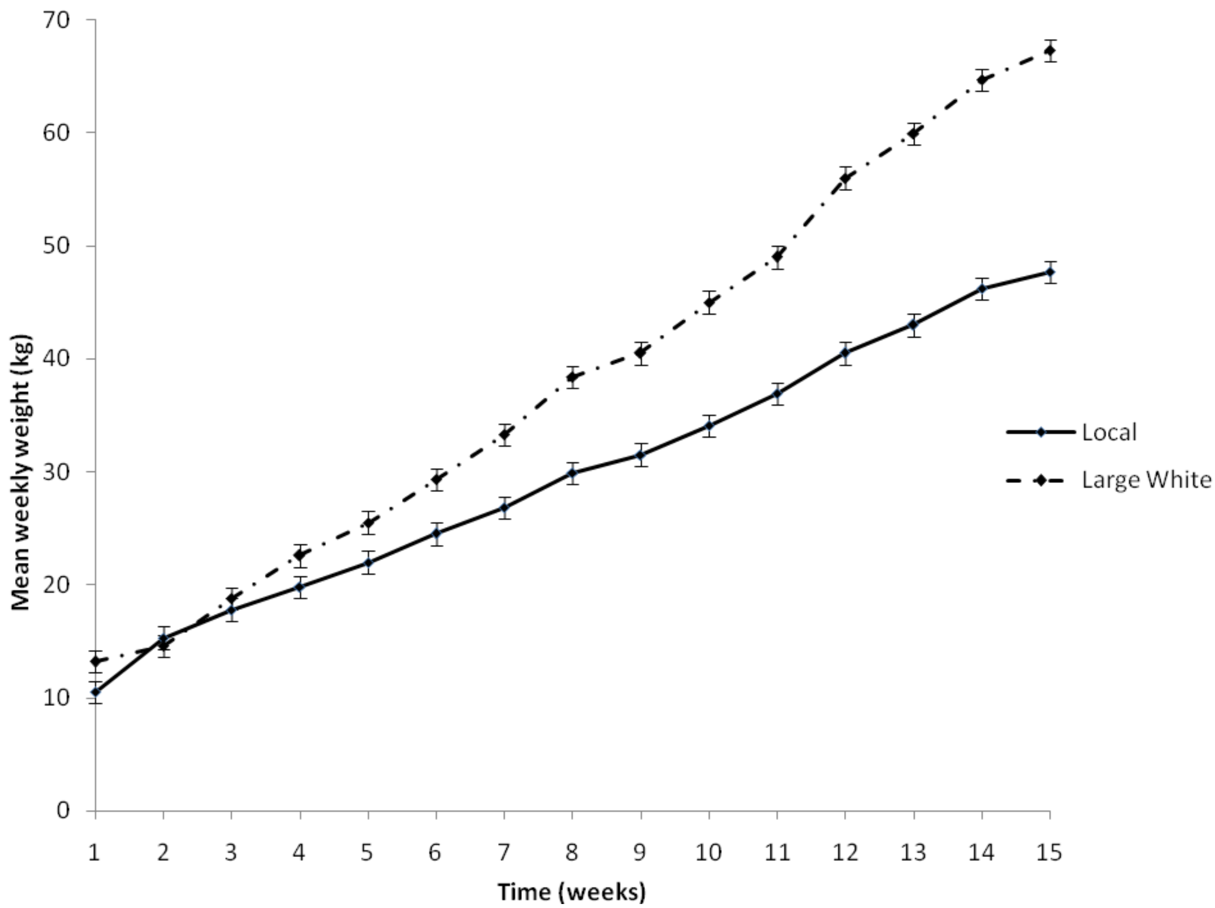

Figure 6.3: Mean (± standard error) weekly body weights for Large White and local pigs for the study period

Table 6.1: Overall performance of local and Large White pigs for the study period

Performance	Local	Large White	Standard error
Average daily feed intake (g)	250.7^{a}	321.3^{b}	2.53
Average daily gain (g)	370.5^{a}	589.4^{b}	12.65
Feed conversion ratio	5.2^{a}	4.4^{b}	0.24
Final weight (kg)	47.7^{a}	67.0^{b}	0.99

^{a,b}Within a row, means with different superscripts differ ($P < 0.05$)

Table 6.2: Pearson's correlations between temperature and performance parameters for local and Large White pigs

Parameter	**Local**	**Large White**
ADFI per kg $M^{0.75}$	0.31***	0.45***
ADG	-0.19*	-0.20**
FCR	0.20**	0.50***

* Correlation coefficient significant ($P < 0.05$), ** ($P < 0.01$), *** ($P < 0.001$).

ADFI per kg $M^{0.75}$ = average daily feed intake per kg metabolic body weight, ADG = average daily gain, FCR = feed conversion ratio.

Table 6.3: Regression of temperature on performance parameters for local and Large White pigs

Genotype	Parameter	Linear	Quadratic	Components of the quadratic equation $y = ax^2 + bx + c$			P-value	R^2
				a	b	c		
LW	ADFI per kg $M^{0.75}$ (g/d)	***	***	-3.68 (0.607)	228.21 (34.913)	-3134.63 (497.475)	0.0001	0.34
LC	ADFI per kg $M^{0.75}$ (g/d)	***	***	-2.54 (0.406)	153.01 (23.377)	-2013.27 (333.101)	0.0001	0.26
LW	ADG	**	**	-0.004 (0.0015)	0.19 (0.085)	-1.88 (1.211)	0.0016	0.07
LC	ADG	*	*	-0.002 (0.0010)	0.11 (0.060)	-1.07 (0.860)	0.0060	0.06
LW	FCR	***	ns	-0.003 (0.0208)	0.77 (1.198)	-14.36 (17.068)	0.0001	0.25
LC	FCR	***	**	-0.06 (0.024)	3.57 (1.396)	-48.72 (19.894)	0.0017	0.07

*Significance level ($P < 0.05$), ** ($P < 0.01$), *** ($P < 0.001$).

LW = Large White, LC = local pigs, ADFI per kg $M^{0.75}$ = average daily feed intake per kg metabolic body weight, ADG = average daily gain, FCR = feed conversion ratio. Figures in parentheses represent standard errors.

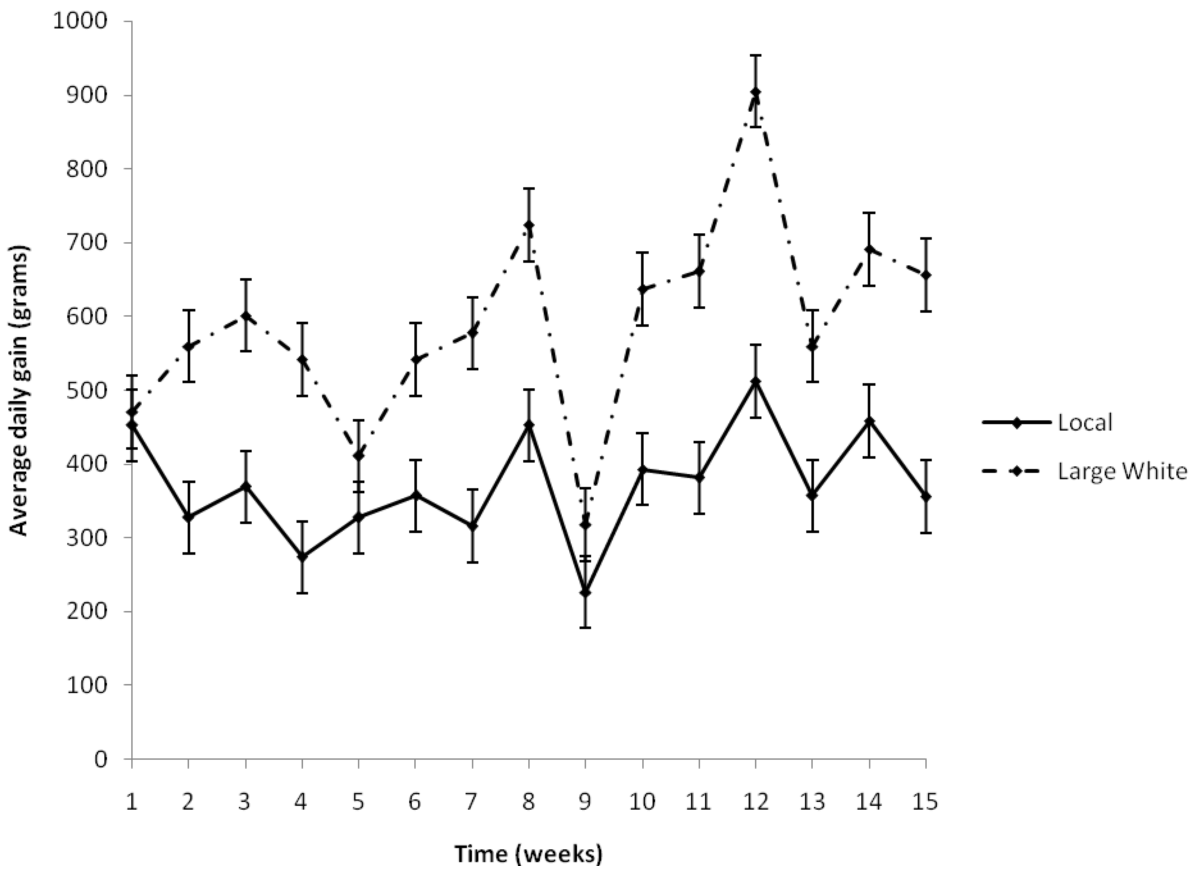

Figure 6.2: Average daily gain (± standard error) for the Large White and local pigs for the study period.

The regression model predicted that ADG starts to decrease at 29 ˚C but the rate of decrease is higher in LW than local pigs. When temperature was highest in Week 9, FCR for the LW pigs was more compromised being 7.6 ± 0.94 while that for local pigs was 4.6 ± 0.94 (Figure 6.5). The overall FCR for LW pigs was more compromised being double the expected value (Table 6.1). The overall FCR for local pigs was at the expected value of 5.2 (Table 6.1). In LW pigs, the Pearson's product moment correlation coefficient between temperature and FCR was more than double that of local pigs (Table 6.2). There was a positive linear relationship between temperature and FCR for LW pigs ($P < 0.001$) and quadratic relationship for local pigs (Table 6.3; $P < 0.01$).

6.5 Discussion

High temperatures experienced in the 9th week and from 13th week onwards might have contributed to the observed drop in ADFI for both pig genotypes. The regression of temperature on ADFI showed higher coefficient values for LW pigs than local pigs implying that the former were more affected. The relationship between temperature and ADFI was quadratic implying that there a peak when temperature started to have a negative effect. For example, ADFI started decreasing at about 32 ˚C in both pig genotypes. However, it is the rate of decrease in ADFI that differed between the two pig genotypes. At high temperatures, ADFI was more compromised for the LW pigs probably to reduce the heat production associated with the digestion and metabolism of nutrients (Wellock *et al*., 2003). The findings suggest that, at temperatures above 34 ˚C, even the local pigs, which are perceived to be more heat tolerant (Nengomasha, 1997; Darfour-Oduro *et al*., 2009) had reduced ADFI. Further research should determine the thermo-neutral zone for local pigs in order to have better understanding about its heat tolerance.

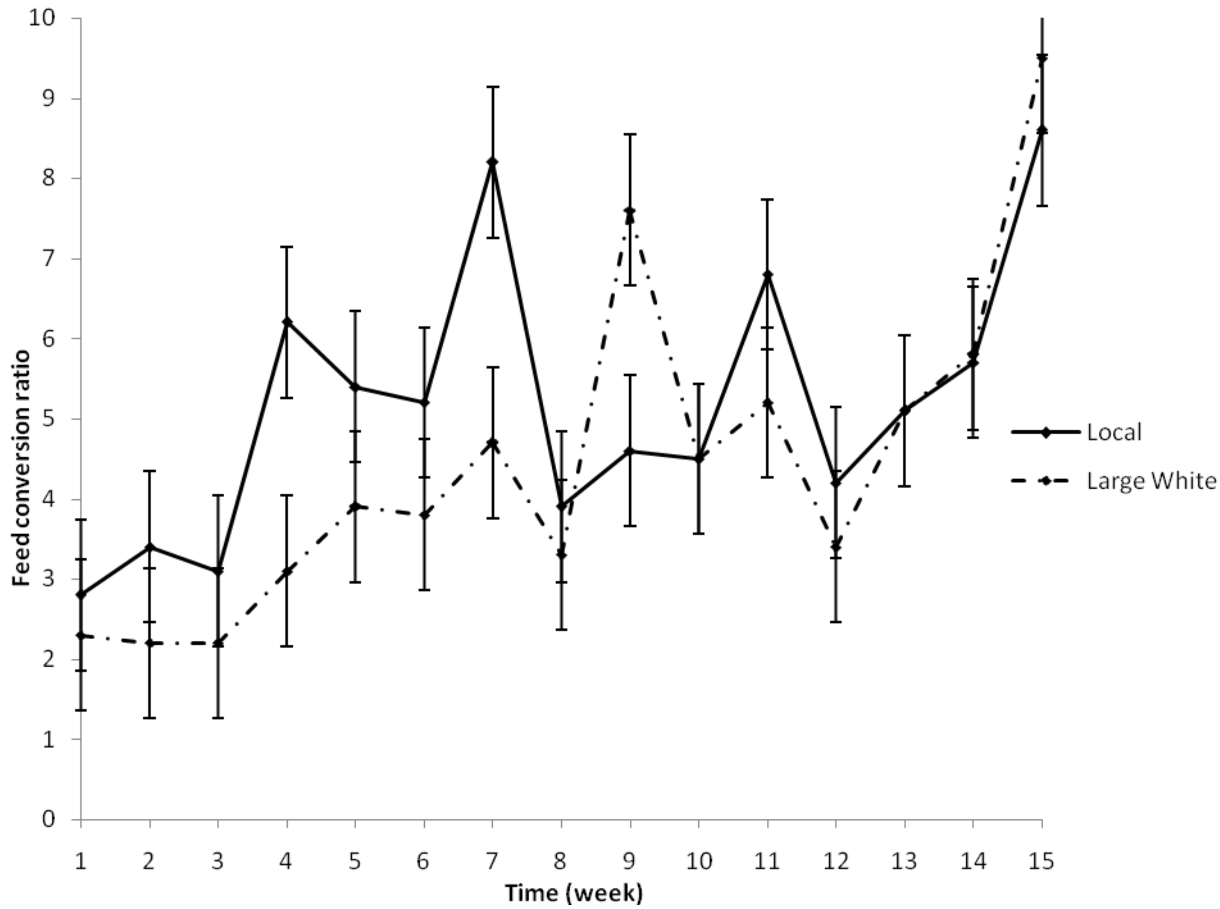

Figure 6.3: Mean (± standard error) feed conversion ratio for the Large White and local pigs for the study period

Large White pigs had reduced ADFI under hot conditions may be because of the limited ability of the pigs to dissipate excess heat (Quiniou *et al*., 2000; Renaudeau *et al*., 2008). Huynh *et al*. (2005) reported that for every 1˚C rise above the thermo-neutral zone, voluntary feed intake decreased by 95.5 g for imported growing pigs. A huge decrease in ADFI in the 9^{th} week agrees with the findings of Serres (1992) who reported a 46 % decrease in voluntary feed intake (VFI) of imported pigs at 32 ˚C. To increase the energy density of the diet, and hence keep energy intake at an adequate level, fat is added to pig feeds during the hot summer months (Hardy, 2005). Less heat is produced by pigs when they digest and utilise fat as compared to the starch and fiber found in cereal grains and plant protein sources (Hardy, 2005).

The ADFI were consistently higher throughout the study period in LW than local pigs probably because the former were improved through selection to consume more to match the high demand for nutrients for growth (Chimonyo *et al*., 2005; 2010). The high demand for feed by the large framed LW pigs might pose a challenge for low-input communal production systems of Southern Africa where there is a critical shortage of feed (Chapter 4). Average daily feed intake was increasing with time in both pig genotypes because they were growing. The ADFI in the current study were higher than 0.11 and 0.12 (kg/kg $M^{0.75)}$ reported for LW and local pigs respectively raised on commercial feed (Kanengoni *et al*., 2004). Commercial feeds might have high levels of energy and protein than what local pigs require hence the observed low feed intake in the current study (Chimonyo *et al*., 2005). In addition, local pigs are slow growers and less efficient in utilising commercial feed hence the low feed intake. The observed constant feed intake for local pigs during the first three weeks post-adaptation period suggest that they needed more time to get accustomed to commercial feeds. Local pigs are known to survive well on leguminous leaf meals, groundnuts hulls, sunflower cakes and fibrous protein supplemented by farmers during free ranging in communal areas (Chimonyo *et al*., 2001; Mashatise *et al*., 2005; Chikwanha *et al*., 2007).

The final weights were lower for the local pigs because genetically they are slow growing and have a small carcass length. Overall, results suggest that local pigs were not affected by high temperatures they were above the 35-40 kg reported for the same genotype Mukota pigs at 5-6 months of slaughter (Chimonyo *et al*., 2005). Local pigs reached their mature weight at the recommended time of 12-16 weeks post-weaning (Kanengoni *et al*., 2004). The disadvantages with smaller carcasses for local pigs are that farmers might realise lower returns and carcasses cannot be cut into specialised cuts like those for LW pigs (Chimonyo *et al*., 2010). The growth curve for local pigs seemed to have peaked at the end of the study period as compared to LW pigs which were still gaining weight. This shows that at 16 weeks post-weaning local pigs had reduced efficiency of feed conversion into muscle since most of the dietary nutrients were converted into fat (Whittemore, 1993). Although LW pigs were more stressed, they managed to convert feed efficiently to weigh more than local pigs by the end of the experiment. More research is required to determine growth curves and development patterns under hot conditions for different pig genotypes to estimate their appropriate ages and body weight at slaughter (Chimonyo *et al*., 2011).

The overall reduced ADFI for LW pigs translated into decreased ADG. The ADG for LW pigs was significantly reduced most likely due to high temperatures in 5th, 9th and 13th weeks. The findings are consistent with some authors who reported a decrease in ADG due to a drop in VFI during heat stress (Serres, 1992; Collin *et al*., 2001). Fitting data to the quadratic model predicted that ADG started to decrease at 29 ˚C in both pig genotypes but the rate of decrease is higher in LW than local pigs. In the current study, LW pigs had a poor ADG (589.4 ± 12.65 g) when compared to 632g/d reported by BPEX (2009) at room temperature. The drop in temperatures in the 12th week encouraged high ADFI hence a high ADG for LW pigs than local pigs. The ADG for local pigs in the current study was higher than that reported for the Mukota (360 g/d) fed on commercial diet (Kanengoni *et al*., 2004). The huge variation in the growth performance of LW pigs over the study period compared to local pigs implied that the former had a compromised performance as a result of high ambient temperatures. Large White pigs might require intervention such as spraying during extremely high temperatures. The differences in growth performance might also be due to genetic differences (Chimonyo *et al*., 2008; Darfour-Oduro *et al*., 2009) since local pigs have not undergone intensive selection for growth as the LW pigs. It is, however, not clear why the Pearson's product moment correlation coefficient between temperature and ADG was negative for both pig genotypes yet for ADFI and FCR it was positive.

The observed increase in FCR for LW pigs in the 9th, 13th, 14th and 15th weeks can be explained by the prevailing high environmental temperatures which compromised their performance. The Pearson's product moment correlation coefficient between temperature and FCR was high for LW pigs indicating that they are more affected by heat stress than local pigs. The regression model for local pigs showed a quadratic function whilst for LW it was linear. This implies that FCR for LW will continue to rise (compromised) with an increase in temperature). The current study showed that as pigs grow, ADFI increased but they became less efficient in converting the feed consumed into ADG, thereby confirming other authors' observations (Collin *et al*., 2001; See, 2007). At temperatures close to or lower than the thermo-neutral zone, the FCR for LW pigs was better than that for local pigs maybe because the former are more efficient at converting dietary nutrients into muscle (Dube *et al*., 2011). The overall FCR of 4.4 for LW pigs was higher (poorer) than that of 2.4 reported by BPEX (2009). In the 15th week when temperature was still high, FCR for LW reached 9.5 which can make the pig production unprofitable. This is a clear indication that LW pigs had reduced growth performance due to high temperatures. The South African local pigs had a similar FCR to that of 5.59 reported for Mukota pigs raised on commercial diets under non stressful conditions (Kanengoni *et al*., 2004). This observation implied that local pigs were performing well despite high temperatures in the current study. Generally, higher FCR for local pigs might suggest the need to feed them on highly fibrous diets such as maize cobs which they can utilise better (Ndindana *et al*, 2002; Nsoso *et al*., 2006; Chikwanha *et al*., 2007). Further studies should assess the performance of South African local pigs when fed on high fiber diets. The inclusion of local pigs in cross breeding programs with LW pigs might produce fast growing pigs but with the ability to adapt to the harsh environmental conditions prevailing in communal production systems of Southern Africa.

6.6 Conclusions

High temperatures significantly decreased ADFI, ADG and FCR in LW than local pigs. It was concluded that high temperatures (beyond the thermo-neutral zone) have a negative impact on the performance of LW relative to local pigs under the natural diurnal heat-related stress. To better understand the importance of heat tolerance, there is need to assess the value farmers place on it relative to other adaptive and productive traits of economic importance under communal production systems of Southern Africa.

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CHAPTER 7: Valuation of the South African local pigs under market- and subsistence-oriented production systems

(Submitted to *Ecological Economics*)

Abstract

Given that local pigs in South Africa are threatened by replacement and uncontrolled crossbreeding with imported pigs, it is important to invest into conservation programmes. Those pig genotypes with optimal socio-economic benefits to farmers and highest genetic diversity should be prioritised for conservation investment. The objectives of this study were to determine farmer preferences for local pig traits and implicit prices for these traits under subsistence- and market-oriented communal production systems of Southern Africa. Results of a choice experiment showed that keeping pigs with high frequency of illness, bought-in feed requirements and low pork quality disadvantaged farmers in subsistence-oriented more than market-oriented production system. Farmers in market-oriented production system derived more benefit from productive traits such as heavier slaughter weights and large litter size than subsistence-oriented farmers. Under the subsistence-oriented production system, farmers in CSF-affected areas placed high prices on adaptive traits than the unaffected areas. Farmers in subsistence-oriented production systems were willing to pay high prices for adaptive traits but prices could not be determined for market-oriented production system. It can be concluded that subsistence-oriented farmers valued adaptive traits while market-oriented farmers valued productive traits. The findings suggest that adapted local pigs can be promoted in subsistence-oriented production

systems while productive imported pigs and their crosses with local pigs can be kept in market-oriented production system.

Key words: Choice experiments, Disease resistance, Foraging ability, Heat tolerance, Litter size.

7.1 Introduction

The culling of CSF-infected pigs affected people's livelihoods in both market- and subsistence-oriented production systems (Chapter 3). Farmers were trying to recover from the devastating effects of the disease by utilising adapted local breeds or their crosses with imported pigs (Chapter 4). Farmers requested impirical studies to identify heat tolerant pig genotypes to mitigate climate change effects (Chapter 4). Local pigs had superior heat tolerant mechanisms than LW pigs (Chapter 5). High temperatures significantly decreased ADFI, ADG and FCR in LW than local pigs (Chapter 6). Although local pigs were found to be more heat tolerant, the contribution of this trait to the pigs' TEV is poorly understood. No attempt has been made to estimate the economic values for preffered local pig traits for resource-limited farmers in Southern Africa. Lack of information on the economic and socio-cultural values for local pig genetic resources contributes to their under-valuation and erosion of biodiversity. Current policies favour the replacement of the local pigs by imported genotypes (Rege and Gibson, 2003; Wollny, 2003). Economic valuation is the basis for making informed decisions about costs and benefits of conservation (Mendelson, 2003; Scarpa *et al*., 2003a). Thus, policy makers can choose between allocation of resources between conservation and alternative uses. For example, incentive structures can be established for the conservation of genetic resources that are not favoured by market systems but could be ideal for the sustainable development of subsistence-oriented production systems (Ruto *et al*., 2008; Zander and Drucker, 2008; Zander, 2011).

In North-West Vietnam, Roessler *et al*. (2008) reported that the values placed on pig traits are likely to vary with production systems. Establishing differences in pig trait preferences across production systems aids policy makers in designing sustainable breeding and conservation programmes. Natural disasters such major disease outbreaks as was the case with CSF in South Africa (NAFU, 2007; WOAH, 2005), result in loss of pigs and are likely to affect the way farmers value this source of their livelihoods. Policy-makers can be provided with better understanding on how culling of CSF-infected pigs in subsistence- and market-oriented production systems might affect the way in which famers value their pigs especially for disease resistance. The information would also form the basis for compensating farmers in the case of future natural disasters.

Assessment of the TEV of non-market goods is achieved by applying a choice experiment (CE), a survey-based stated preference method (Bateman *et al*., 2003; Freeman, 2003). Stated preference methods have been increasingly applied in the animal genetic resource sector in the last ten years (e.g. Ouma *et al*., 2007; Omondi *et al*., 2008; Kassie *et al*., 2010). Despite growing interest in the economic valuation of pig genetic resources (Scarpa *et al*., 2003b; Drucker and Anderson, 2004; Roessler *et al*., 2008), there have been no empirical studies reporting TEV of local pig genetic resources in Southern Africa. The objectives of this study are to determine farmer preferences for pig traits relative to each other in CSF-affected and unaffected areas under subsistence- and market-oriented production systems, and determine implicit prices for these traits.

7.2 Materials and Methods

7.2.1 Study site

The study was conducted from April to June 2010 in communal production systems of three municipalities in the Eastern Cape Province of South Africa. These municipalities differed in their dominant production systems for pigs and the outbreak of CSF disease: Elundini (CSF-affected and subsistence-oriented), Ntabankulu (CSF-unaffected and subsistence-oriented) and Ngqushwa (CSF-affected and market-oriented). Under the market-oriented production system, there were no CSF unaffected areas that were identified. The sites were chosen after the CSF outbreak and policy-makers needed information to restock pigs. Selection of sites involved the participation of state veterinary services, University of Fort Hare, councilors, farmer representatives and government officials. Communities in Ngqushwa Municipality were producing pigs for commercial sale to abattoirs, supermarkets or butcheries in the nearby King Williams (20 km) and Peddie (3 km) towns. Farmers in market-oriented pig production system were buying supplementary feeds and obtained more income from pigs. Elundini and Ntabankulu Municipalities composed of rural communities that were resource-limited and raised pigs on free ranging mainly for household consumption or selling in the neighbouring households. Key informants classified those respondents with less than five herds of cattle or an equivalent of 20 small stocks (sheep, goats or sheep) as resource-limited while the other group was regarded as less resource-limited.

7.2.2 Sampling

Choice experiment data were collected using semi-structured questionnaires and in-depths interviews with key informants. Households with pigs were identified with the assistance of the headmen and the snowballing technique was used to select all participants who were willing to participate in the project. The number of households interviewed in Elundini, Ngqushwa and Ntabankulu were 102, 108 and 78, respectively.

7.2.3 Choice experiment design and procedure

Choice experiments are based on consumer demand theory (Lancaster, 1966; Rosen, 1974), stipulating that consumers not only derive utility from a good *per se* but from the complex of different characteristics embodied in the good (Louviere *et al*., 2000). Choice experiments employ surveys in a hypothetical manner allowing respondents to make trade-offs between combination of pig traits that are presented in the choice sets. The decision regarding which traits and their levels to use in the CE was based on literature reviews (Scarpa *et al*., 2003b; Drucker and Anderson, 2004; Roessler *et al*., 2008) and in depth pilot study conducted in August to December 2009. Key informants included extension officers, veterinary specialists, councilors, village headmen and elders (over 70 years of age). Secondary information was obtained from the Department of Agriculture, South Africa, pig producers association and non-governmental organisations (NGOs).

The traits that were identified for the CE by farmers in various production systems are shown in Table 7.1. The CE was designed in such a way that the farmer preference for a particular trait

Table 7.1: Pig breeding traits and levels selected by farmers for the choice experiment

Aggregate trait	Focus trait	Levels
Productivity	Litter size	1-3 piglets
		4-6 piglets
		> 6 piglets
Heat tolerance	Watering frequency per day	Once
		Twice
		Thrice
Disease tolerance	Frequency of illness	Rare
		High
Pork quality	Pork quality	Low
		High
Foraging ability	Feed purchase requirements	Yes
		No
Growth rate	Live weight at 8 months (kg)	40
		60
		80
Market price	Market price of 1 year old sow	R350
		R800
		R1200

Exchange rate: 1USD = R7 (South African Reserve Bank, 2010).

level could be associated with a particular pig genotype without explicitly including it in the individual pig profiles. The rationale behind choosing each trait and levels is given below.

1. Frequency of illness was used as a proxy for disease resistance. This trait is important in communal production systems because most people are poor and cannot access medicine or veterinary services. Health and disease resistance constitute indirect use-values, indirectly influencing productivity of local pigs. Pigs were considered as either having high frequency of illness or rarely get ill.
2. Live weight was used as a proxy for growth rate. Local pigs were considered to reach slaughter weight at about 8 months of age under scavenging feed resource base. Body weight also provides a classical use-value and this distinguishes local pigs from crossbreeds and imported genotypes.
3. Prices are thought to depend on body size and health status at the time of purchase. The levels of priced that were used (R350, R800 and R1200) were the average market prices for a 1 year old sow for the 3 municipalities.
4. Feed purchase requirement (need for bought-in feeds) was used as a proxy for foraging ability. The ability to consume a variety of feeds is an important trait for pig production in communal production systems. Pigs are mainly fed on farm produced feed resources such as maize, vegetables and kitchen wastes.
5. Litter size was used as a proxy for productivity of the pigs. Without dietary restrictions, improved and imported pigs have superior reproductive performance compared to local pigs (number of litters per year, number of piglets born alive). The levels used in the study are what farmers considered as low (1-3), medium (4-6) and high (> 6) productivity of pigs.

6. Watering frequency was used as a proxy for heat tolerance. High frequency of drinking water indicates that the pigs are struggling from heat stress and will be trying to cool down. This trait is becoming more important with prospects of climate change.
7. Pork quality referred to pork characteristics that make it favourable such as flavour and taste. Key informants considered pork to be either high or low quality.

Given that four traits had three levels and the remaining three traits had two levels, there were 648 ($3^4 * 2^3$) possible pig profiles in a full factorial design. These were reduced to a manageable size of 72 profiles using the SAS (2006) procedure of Kuhfeld (2003) to come up with orthogonal or fractional factorial design. The design ensured the identification of the main effects with a minimum number of profile combinations. The profiles were then randomly paired such that a choice set with uncorrelated traits was generated. Descriptive cards in local *Xhosa* language with pictorial illustrations were used to enhance clarity of comparisons. A choice set consisted of two cards and a "no-buying" option (Appendix II). If neither choice was found to be satisfactory, the respondent would choose the "no buy" option and state that he/she preferred neither. Providing the "no buy" option is consistent with demand theory where people are not supposed to be forced to buy goods with no utility gain (Bateman *et al*., 2003).

7.2.4 Data collection

After the collection of socio-economic data, each respondent was introduced to the type of choice task required. There were 36 choice sets which were blocked into six. Individuals were introduced to six choice sets of the 36 choice sets, i.e. one of the six blocks. Each respondent was hypothetically buying for rearing one of the available pig profiles, each described by the relevant traits. A total of 1728 (288 × 6) observations were obtained.

7.2.5 Statistical analyses

The PROC FREQ procedure of SAS (2006) was used to analyse the effects of socio-economic data except for mean household size and mean household income per year where the PROC MEANS procedure was used. The choice data were analysed using an econometric software NLOGIT/LIMDEP (2007). The choice data were estimated using a series of random utility models and estimators based on likelihood simulation using the mixed logit model (MXL) also known as the random parameter logit (RPL) model as outlined in literature (Train, 1998; McFadden and Train, 2000). The MXL model builds up from the basic multinomial logit (MNL) model that assumes that each individual chooses the alternative that has the highest perceived utility (McFadden, 1974). Utility in this context means how well off a farmer is from keeping pigs. The MNL model is written as:

$U_{in} = X_{in}\beta + \varepsilon_{ij}$, $j = 1,2,\ldots, J_n \in C_{ns}$

Where:

$n = 1,\ldots, n$ denotes individuals;

$i,j = 1,\ldots, J_n$ = alternatives;

C_{ns} , $s = 1,\ldots, S$ is the choice set faced by an individual n;

X_{in} = matrix characterising traits of i,j alternatives for an individual n;

β= a comfortable vector of unknown parameters; and

ε_i = error term.

The model assumes that the error terms are independently and identically distributed (IID) across alternatives and observations. McFadden (1974) reported that this conveniently allows the use of a closed-form expression for the probability P of an individual i choosing alternative j from a choice set C as:

$P_{i(j)} = \exp(\beta' x_{ij}) / \Sigma_k \exp(\beta' x_{ik})$ j; k Є C

The IID assumption can often be violated in which case the MNL model is insufficient. The use of MXL models relaxes the IID assumption. Mixed logit models can further allow for preference heterogeneity in the sample and for panel data (that is many choices made by one respondent). Unlike the MNL model, the MXL model does not have a closed form and probabilities are obtained through simulation from integrals of the standard logit probabilities over all possible values of β following a chosen distribution (Scarpa and Willis, 2010).

Implicit prices for pig traits, expressed as willingness to pay (WTP) or willingness to accept (WTA) compensation were derived from MXL models by calculating the ratio $-\beta_j/\beta_{price}$, where β_j is the coefficient for the pig trait and β_{price} is the monetary attribute, which is associated with costs of obtaining the pig with that specific trait (Train, 2003). Negative mean implicit prices implied that switching to a certain pig trait constituted a cost rather than a benefit hence leaving pig-keeping farmers worse-off. Farmers would then accept a certain amount of compensation for keeping pigs with detrimental traits. Because the coefficients are derived from a MXL model, the WTP/WTA estimates need to be approximated by simulation (Hess, 2010). The values of β_j are drawn from their given distribution, repeated many times (10,000 draws were used).

Ordinal variables (frequency of illness, feed purchase requirements, pork quality and watering frequency) were effects type coded to avoid linear dependency syndrome by including dummy variables. One level of these was omitted as a base level (high pork quality, once a day watering frequency, no feed purchase requirements and rarely get ill). Estimated coefficients for the remaining trait levels indicated the value farmers placed on the change from the base level to other level. Estimates levels for the numerical variables (live weight and number of piglets) indicated the value farmers assigned to a weight increase of 1 kg and a decrease in litter size by one piglet.

First, all data were pooled (to increase the data set and get a more accurate estimate of all communal farmers' perceptions) and analysed using all traits to estimate regression parameters and welfare estimates for all farmers. Secondly, individual analyses were done for the CSF-affected and subsistence-oriented, CSF-unaffected and subsistence-oriented, CSF-affected and market-oriented production systems to specifically reveal differences across these three systems with different levels of CSF and to calculate implicit prices for all of them.

7.3 Results

7.3.1 Socio-economic profiles

The socio-economic profiles for the CSF-affected and unaffected areas which were under subsistence-oriented production system; and CSF-affected area under market-oriented production system are shown in Table 7.2. The average household size was 6 (standard deviation = 3) across the production systems. Most households were headed by females and they were also the major owners of pigs (Table 7.2). The majority of respondents were Christians with a few being African traditional believers. Most of these respondents were resident on the farm, unemployed and had less than seven years of formal education. Market-oriented production system had the highest number of respondents who were selling pigs. In all production systems, the majority of the respondents indicated that they had understood the CE very well (Table 7.2). There were few people across the production systems opting not to buy a pig because of its affordability,

Table 7.2: Socio-economic data for households in classical swine fever affected and unaffected areas under subsistence and market-oriented production systems

Socio-economic parameter	**CSF-affected (SO) n = 102**	**CSF-affected (MO) n = 108**	**CSF-unaffected (SO) n = 78**
Respondents who were female head of households	68	47	58
Respondents who were married	68	65	62
Respondents with < 7 years of formal education	51	89	83
Respondents who were unemployed respondents	77	83	91
Respondents who Christians	97	75	83
Respondents who regarded pigs as very important	83	98	85
Respondents who consumed pork	85	85	90
Respondents who were selling pigs	81	96	65
Respondents who were resource-limited	65	79	87
Respondents who were women owning pigs	70	63	69
Respondents who understood CE	95	92	76
Respondents who could not afford to buy pigs	4	0	3
Respondents who did not buy dissatisfying pigs	8	15	5
Respondents who wanted pig destocking	4	1	0
Average household income per year (standard deviation)	R977.76 (1180.12)	R5395.82 (3720.00)	R2101.21 (3595.620

CSF = classical swine fever, MO = market-oriented production system, SO = subsistence-oriented production system, CE = choice experiments.

unsatisfactory traits and the desire to destock (Table 7.2). Respondents in the market-oriented production system were getting more money from the selling of pigs than those in the two subsistence-oriented production systems.

7.3.2 Preferred trait levels

All traits were included as random parameters in the MXL model. A series of models was then estimated with different distributions for the random parameters and the normal distribution was found to be the best. The pooled model for all production systems had a good fit with a McFadden Pseudo R^2 value of 0.39, indicating an extremely good fit. Generally, all farmers in communal production systems considered all the specified pig traits as important when selecting a breeding sow except watering frequency which was a proxy for heat tolerance (Table 7.3). As expected and indicated by the negative sign of the price coefficient, all farmers preferred cheaper pigs. Sick pigs presented the greatest disadvantage to farmers followed by those with low reproductive performance and whether it required purchased feeds (proxy for foraging inability). Heaviest pigs at 8 months had the greatest benefit to farmers. The standard deviations were highly significant for all traits, implying that preferences for these traits are different across the sample.

When looking at the separate models for the different production systems, it was found that many traits were insignificant. There was stepwise deletion of the insignificant ones such as heat tolerance and only the results of the best fitting models are presented here. Log-likelihood ratio tests were used to compare the restricted models with the model including all variables.

Table 7.3: MXL estimates and implicit prices (Rands) for all farmers

Traits	Coefficient	SE	*P*-value	Implicit price
Random parameters in utility functions				
Low pork quality	-1.165	0.0920	<0.0001	-2890
Litter size: 1-3 piglets	-0.942	0.0911	<0.0001	-2336
Litter size: 4-6 piglets	-0.177	0.0912	0.0522	-439
High frequency of illness	-1.347	0.0864	<0.0001	-3339
Watering frequency: twice a day	-0.033	0.0926	0.7240	na
Watering frequency: thrice a day	-0.060	0.0959	0.5308	na
Weight at 8 months: 80 kg	0.699	0.0942	<0.0001	1734
Weight at 8 months: 60 kg	0.249	0.0919	0.0068	616
Feed purchase required	-0.503	0.0885	<0.0001	-1247
Non-random parameters				
Price	-0.0004	0.00011	0.0004	
No animal	-9.096	0.4553	<0.0001	
Derived standard deviations of parameter distributions				
Low pork quality	1.089	0.0876	<0.0001	
Litter size: 1-3 piglets	0.742	0.0661	<0.0001	
Litter size: 4-6 piglets	0.742	0.0661	<0.0001	
High frequency of illness	1.140	0.0875	<0.0001	
Watering frequency: twice a day	0.498	0.0841	0.0011	
Watering frequency: thrice a day	0.257	0.0783	<0.0001	
Weight at 8 months: 80 kg	0.595	0.0783	<0.0001	
Weight at 8 months: 60 kg	0.595	0.0602	<0.0001	
Feed purchase is required	0.994	0.0856	<0.0001	
Log likelihood function	-1164.682			
McFadden Pseudo R-squared	0.39			
Chi squared	1474.032			

Exchange rate 1USD = R7 (South African Reserve Bank, 2010), na = no price because the trait was insignificant, SE = standard error.

Farmers in subsistence-oriented production system who were affected by CSF selected their sows based on health status, reproductive performance, whether it required purchased feeds, pork quality and weight at 8 months (Table 7.4). Farmers in CSF-unaffected municipality who were under subsistence-oriented production system indicated that pigs that fall sick more often had the highest negative effect on their livelihoods followed by feed purchase requirements, low pork quality, poor reproductive performance and feed purchase requirements (Table 7.4). Weight at 8 months was not important for farmers in CSF-unaffected area which was under subsistence-oriented production system.

For the CSF-affected area which was under market-oriented production system, poor reproductive performance had the greatest negative effect on their livelihoods followed by poor health and low pork quality (Table 7.4). Feed purchase requirement was not important for farmers in market-oriented production system when they chose pigs in the choice sets. Pig price had a positive effect on farmers' livelihoods in market-oriented production system. In all circumstances, heaviest pigs at 8 months (80 kg) were preferred compared to pigs of 40 kg and 60 kg (Tables 7.3 and 7.4).

7.3.3 Implicit prices for trait levels

Implicit prices for the pooled data set showed that all farmers in market- and subsistence-oriented production systems were willing to accept the highest compensation (R3339) for keeping a pig that falls sick often followed by low pork quality (R2390) and the one which give small litters of 1-3 piglets (R2336) (Table 7.3).

Table 7.4: MXL estimates for CSF-affected and unaffected areas under market- and subsistence-oriented production systems (with only significant traits)

Traits	**CSF-affected (SO) n = 102**		**CSF-affected (MO) n = 108**		**CSF-unaffected (SO) n = 78**	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Random parameters in utility functions						
Low pork quality	-1.81***	0.359	-0.99***	0.167	-0.64***	0.160
Litter size: 1-3 piglets	-0.90***	0.229	-1.23***	0.198	-0.568***	0.176
Litter size: 4-6 piglets	na	na	-0.35*	0.170	na	na
High frequency of illness	-2.37***	0.353	-1.13***	0.184	-0.888***	0.116
Weight at 8 months: 80 kg	0.88***	0.231	0.93***	0.183	na	na
Weight at 8 months: 60 kg	na	na	0.29	0.171	na	na
Feed purchase required	-1.21***	0.318	Na	na	-0.565***	0.170
Non-random parameters						
Price	-0.001*	0.000	-0.0005	0.000	-0.001***	0.000
No animal	-13.46***	1.610	-6.75***	0.857	-8.243***	0.506
Derived standard deviations of parameter distributions						
Low pork quality	1.55***	0.352	0.85***	0.195	0.885***	0.123
Litter size: 1-3 piglets	0.90***	0.306	0.62***	0.189	1.262***	0.214
Litter size: 4-6	na	na	0.62***	0.189	na	na
High frequency of illness	1.30***	0.393	1.10***	0.211	0.885***	0.120
Weight at 8 months: 80 kg	0.93***	0.302	0.38*	0.177	na	na
Weight at 8 months: 60 kg	na	na	0.38*	0.177	na	na
Feed purchase is required	2.10***	0.434	na		1.145***	0.145
Number of observations	612		648		648	
Restricted Log Likelihood	-672.22		-710.80		-516.35	
McFadden Pseudo R^2	0.50		0.37		0.35	
Chi squared	667.00		530.86		365.29	

*Significant difference at $P < 0.05$, ***Significance $P < 0.0001$, CSF = classical swine fever, MO = market-oriented, SO = subsistence-oriented, SE = standard error, na = not applicable.

Farmers wanted a compensation of R1247 for moving from a baseline of a pig with good foraging ability to the one which need purchased feed. All communal farmers were willing to pay a high price (R1734) for a pig that weighs 80 kg at 8 months and less money for a 60 kg pig (Table 7.3). Respondents in CSF-affected area which was under subsistence-oriented production were the only ones whose willingness to pay for heaviest pigs at slaughter could be calculated (Table 7.5). Farmers in classical swine fever affected area which was subsistence-oriented wanted the highest compensation for keeping a pig that falls sick more often followed by those producing low pork quality and those that required bought-in feeds. On the other end, farmers in CSF-unaffected area which was subsistence-oriented wanted high compensation for pigs that required purchased feed followed by those with high frequency of illness and small litter sizes (Table 7.5). Pigs producing low pork quality and small litters were not wanted in both CSF-affected and unfected areas under subsistence-oriented production system. No implicit prices could be calculated for market-oriented production system because price was not significant (Tables 7.4).

7.4 Discussion

For the pooled data and subsistence-oriented production systems, the price attribute had a negative sign as expected, showing that farmers did not want expensive sows. It was however, surprising that price had an insignificant sign in the model for market-oriented farmers. This could signify that farmers did not consider the issue of price since the long term benefit of getting a pig with good breeding traits outweighed the cost of buying it. In this case, they would be prepared to pay any price because their high income levels allowed them to do that.

Table 7.5 Implicit prices for pig traits in CSF-affected and unaffected areas under market- and subsistence-oriented production systems

Traits	**CSF-affected (SO)**	**CSF-affected (MO)**	**CSF-unaffected (SO)**
	Implicit price (Rands)	Implicit price (Rands)	Implicit price (Rands)
Low pork quality	-3147	na	-900
Litter size: 1-3 piglets	-1571	na	-905
Litter size: 4-6 piglets	na	na	na
High frequency of illness	-4125	na	-1017
Weight at 8 months: 80 kg	1530	na	na
Weight at 8 months: 60 kg	na	na	na
Feed purchase required	-2101	na	-1413

na = not applicable because either the trait or the price was not significant.

CSF = classical swine fever, MO = market-oriented, SO = subsistence-oriented, Exchange rate: 1USD = R7 (South African Reserve Bank, 2010).

Omondi *et al*. (2008) reported positive but significant results for bucks in Kenya because they were considered giffen goods whose price rises with increase in breeding value and quality. Imported pigs which are commonly found in market-oriented production system are usually priced highly than the small framed local ones (Chimonyo *et al*., 2010). It could also be that if the upper levels for the price attribute were higher in the experimental design, farmers would have been more inclined to choose less expensive sows leading to a significant and negative coefficient for the price attribute. For affluent farmers in market-oriented production system, some presented price levels might have been simply too low to make a trade-off with another trait.

Some trait levels showed negative estimates of β, signifying that they had negative effects on farmers' utility levels, and were considered unattractive, a result also observed by Roessler *et al*. (2008). The fact that frequency of illness had the highest negative coefficient value for pooled farmers' data and both subsistence-oriented production systems might imply that health status of the pig had the strongest influence on respondents' choices (Roessler *et al*., 2008). Most of these subsistence-oriented farmers were located in the rural areas are poor; illiterate and could not afford to buy conventional drugs to treat their pigs (Chapter 3). This together with the fact that most farmers were indigent, might have forced them to prefer local pigs which rarely get sick when compared to imported pigs (Zanga *et al*., 2003). Farmers in CSF-affected and CSF-unaffected subsistence-oriented production systems were all concerned about keeping sick pigs as it was the most important trait affecting their livelihoods negatively. Farmers in market-oriented production system did not consider high frequency of illness as the most important factor may be because they were close to veterinary services and could afford to buy drugs.

Low pork quality had negative effect on farmers' livelihoods in all production systems because farmers preferred pig genotypes which produce high pork quality (eating quality based on farmer perceptions). The disadvantage of keeping pigs which produce low pork quality was, however, highest in market-oriented production system because they are the ones affected most by negative consumer perceptions or preferences. Farmers in both subsistence-oriented production systems considered quality of pork as the second most important factor affecting their livelihoods as pigs are important for food security. Local pigs were generally preferred over imported ones in terms of pork quality because it is perceived to be natural (raised on free ranging system and without additives) and has a better taste (Chimonyo *et al*., 2005; 2010). Despite this important trait, local pigs are discriminated on the conventional market because of their black colour and small carcasses which cannot be cut into specialised cuts (Chimonyo *et al*., 2010). This discriminatory treatment means that the local pigs continue being pushed out of conventional food producing systems. Local pigs continue being replaced by imported pigs which do not support sustainable development in subsistence-oriented production systems because of their high demand for veterinary and feed inputs. There is room for creating a niche market for natural pork from local pigs in market-oriented production system to support health conscious population (Chapter 4). Chimonyo *et al*. (2005) reported that most fats in local are subcutaneous which can easily be removed unlike those for imported pigs which are intramuscular thereby presenting a health risk to consumers.

The fact that all farmers disliked pigs that give smaller litter sizes of 1-3 indicates that they consider reproductive performance as important. Large litter size determines potential for profit maximisation (Roessler *et al*., 2008) hence it was imperative for the farmers in market-oriented production system to consider it as the most important trait affecting their livelihoods. Low reproductive performance is associated with local pigs hence these farmers might have preferred better performing imported genotypes in terms of litter size (Chimonyo *et al*., 2011). This finding is inconsistent with subsistence-oriented farmers' choice for pigs that rarely get sick which is associated with local pigs or crossbreds. Litter size was not a major concern for farmers in the two subsistence-oriented production systems because they wanted piglets they could sustain since they experience feed shortages (Chapter 4). In most cases, these farmers sell excess piglets after weaning at two months. Local pigs which produce an average of seven piglets per litter (Ndiweni and Dzama, 1995) might be ideal for farmers in subsistence-oriented production systems. The findings from the study could be used in designing crossbreeding program that exploits breed complementarity and heterosis. Planned crossbreeding program minimise the risk of loss of the local pigs' gene pool and also tries to achieve the farmers' desire to balance productive and adaptive traits.

The finding that subsistence-oriented farmers did not want pigs that require feed purchases was expected. Resource-limited communal farmers did not want pigs with high monetary costs. Feed costs account for the greater part of the variable costs accounting for approximately 84 % in Northern Vietnam (Lemke *et al*., 2007). Raising imported pigs is associated with high feed costs because they are not good foragers like local pigs (Chimonyo *et al*., 2005; Mashatise *et al*., 2005). Imported pigs have high feed requirements which are not easily met by the free ranging feed resource base (FRFRB). On the contrary, the slow growing local pigs are adapted to fibre-rich diets obtained from the FRFRB (Kanengoni *et al*., 2004; Chikwanha *et al*., 2007). The issue of feed costs (from buying supplementary feed) was not a problem to the market-oriented farmers because they wanted to maximise their return on investment. These farmers are prepared to buy feed for their pigs because the profit they obtain after selling these pigs surpasses the total variable costs. Based on feed costs requirements, subsistence-oriented farmers might prefer local pigs for their adaptive traits while the market-oriented farmers prefer productive imported pigs.

The issue of heat tolerance was not significant when farmers were selecting breeding sows across production systems although it was earlier highlighted as important during the pilot survey (Chapter 4). This was surprising considering that farmers were complaining about climate changing to hot conditions which required adapted pig genotypes. Non significance of this trait may arise from the complexity of this attribute as was also reported with body conformation in Northern Vietnam (Roessler *et al.*, 2008). It is difficult for the farmer to associate heat tolerance with anything tangible when selecting the breeding stock. This trait could be asked directly during CE studies without using watering frequency as a proxy. Non-significance might also indicate that heat tolerance was not critical relative to other traits that were being selected for.

Slaughter weight had the expected positive regression coefficient for most production systems because heavier pigs provide more pork and they fetch higher market prices (Roessler *et al.*, 2008). Slaughter weight can also be used as a proxy for growth rate. Market-oriented farmers were expected to have the highest benefits from the heaviest pigs at 8 months. It is however, not clear why the monetary value for live weight was lower for market-oriented than CSF-affected areas which were under consumption-oriented production system. Farmers in subsistence-oriented production system which was affected by CSF might have preferred heavier pigs at slaughter to compensate for their preference for genotypes producing smaller litters which they could sustain. The culling of all pigs in this production system might have jeopardised the farmers' source of livelihoods hence they tried to increase animal protein by selecting for pigs with heavier slaughter weight. Observations in the field revealed that farmers were restocking pigs on their own whilst anticipating a major restocking programme from the government of South Africa.

Keeping few but heavier pigs might indicate farmers' intelligence in trying to meet food security and at the same time minimising the risk of a major loss in the event of another disease outbreak. Results suggest that farmers in the market-oriented production system would prefer keeping fast growing imported pigs while those in the subsistence-oriented production system which was affected by CSF keep crossbreds of local and imported pigs. In CSF-unaffected area which was under consumption-oriented production system, farmers were not concerned about live weight because their production goal was for food security instead of profit (Chapter 4). The fact that pigs were not culled in this area implied that farmers' source of livelihoods was not threatened hence there was no need to adjust their pig selection criteria. This suggests that farmers in this subsistence-oriented production system would be comfortable to continue keeping their local pigs which have light weight at slaughter. The light weight also entails that these pigs have low feed demand hence are sustainable under resource-limited conditions.

Implicit prices for most significant traits except live weight had negative mean estimates implying that switching to those pig traits constituted a cost rather than a benefit hence the measure became a WTA compensation for keeping pigs with detrimental traits (Roessler *et al*., 2008). Pooled data for farmers showed that they were willing to accept the highest compensation for moving from the baseline of a pig that rarely get sick to the one with poor health status because it is the most important trait to them. Farmers also wanted higher compensation for switching from a pig with high pork quality (in terms of eating quality) to the one with low pork quality. All farmers required high compensation for keeping those pigs with poor foraging ability. In all the above cases it would be easier to encourage farmers to keep local pigs compared to imported genotypes. The challenge would be where farmers wanted compensation for keeping sows with low reproductive capacity typical of local pigs (Chimonyo *et al*., 2011). The fact that they were willing to pay higher prices for heaviest pigs also disadvantages the local pigs which are lighter in weight (Chimonyo and Dzama 2007; Chimonyo *et al*., 2008). Based on the positive value for weight, the imported pigs and their crossbreds would stand a chance of being kept without need for compensation. This scenario will effectively threaten the conservation of local genotypes which have indirect use and option values (Drucker and Anderson, 2004).

The fact that subsistence-oriented farmers in CSF-affected area attached higher compensation values to detrimental pig traits than the disease free area suggests that the culling due CSF outbreak (WOAH, 2005) led to higher appreciation of pigs' contribution to people's livelihoods. This observation was not witnessed in a similar production system which never experienced the devastating effects of CSF and farmers were still willing to accept lower compensation values for keeping pigs that falls sick often. Respondents in CSF-affected area under subsistence-oriented production system attached higher monetary values on adaptive traits than for the pooled farmers because they were concerned about pig survival under minimum management levels. Heavy weight at 8 months (80 kg) constituted a benefit to farmers in CSF-affected area under subsistence-oriented production system hence farmers were the only ones who were willing to pay a high price. It is not clear why farmers in the CSF-unaffected area which were under a similar production system were willing to accept the highest compensation for pigs which required bought-in feeds. Respondents in CSF-affected area under subsistence-oriented production system were willing to accept higher compensation for keeping pigs with smaller litter size than the unaffected area may be because the former wanted good producing pigs to restock the culled ones. These farmers in CSF-affected area might have realised that the disease compromised pork quality hence their willingness to accept high compensation price for keeping pigs that produced low pork quality when compared to their CSF-unaffected counter-parts. The disease might have affected pork quality because it is associated with fever, haemorrhages, weight loss, the loss of appetite and skin discolouration from internal bleeding (Widjojoatmodjo *et al*., 1999; Wehrle *et al*., 2007).

7.5 Conclusions

Unfavourable adaptive traits such as feed purchase requirements and high frequency of sickness constituted a greater disadvantage to farmers in subsistence-oriented farmers than in the market-oriented production system. Farmers in the market-oriented production systems derived more benefit from productive traits such as heavier weights at 8 months than subsistence-oriented farmers. Economic values for traits were high for subsistence-oriented production system but could not be determined for the market-oriented production system. The CSF-affected area under subsistence-oriented production system valued pigs more for adaptive traits than the CSF-unaffected area. Subsistence-oriented farmers who were affected by CSF wanted a compensation price of R10 944.00 (USD1563.43) for keeping a pig genotype with unfavourable traits when compared to R4235.00 (USD605.00) for their CSF-unaffected counterparts. Subsistence-oriented communal farmers preferred adapted local pigs while the market-oriented farmers preferred high performing imported pig genotypes and their crosses with local pigs.

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CHAPTER 8: General discussion, conclusions and recommendations

8.1 General discussion

The broad objective of the study was to determine the economic value of local pigs in market- and subsistence-oriented production systems in communal areas of Southern Africa. The main hypothesis tested was that local pigs have similar economic values in market- and subsistence-oriented production systems of Southern Africa. The study was necessitated by the fact that climate is changing to hot conditions in Southern Africa and could be associated with disease outbreaks, water and feed shortages for pigs. Pig genotypes that are drought tolerant, disease tolerant and heat tolerant should be conserved so that they contribute to future breeding programmes. Adaptive traits have the potential to increase the local pigs' economic value and prevent their continued replacement with imported pig genotypes under communal production systems. This is important considering that local pigs are a source of livelihood for resource-limited farmers providing food (animal protein), income and insurance against drought. Prior to economic valuation of local pig genetic resources, it is important to investigate farmer perceptions of CSF outbreak in communal production systems and to reveal differences in the way farmers were affected by and dealt with the outbreak.

The hypothesis tested in Chapter 3 was that farmer perceptions, effects on pig production and handling of the disease outbreaks in market- and subsistence-oriented production systems that were located in coastal and inland areas were similar. Resource-limited farmers in subsistence-oriented production system were more likely to experience pig diseases than their resource-rich counterparts in market-oriented production system. Most of the pigs that were culled during the

2005 CSF outbreak in South Africa were from areas located along the coast, perhaps because of the pattern of spread of the disease which emanated from a coastal town of Centane (Department of Agriculture, 2006). Coastal areas are known to harbour many diseases because of the hot humid conditions when compared to inland areas (Rowlands *et al*., 2008; Jutla *et al*., 2010; Ortiz-Pelaez *et al*., 2010). Although the chance of disease outbreak was high in coastal areas and subsistence-oriented production system, it was established that the disease had equally devastating effects once there was an outbreak even irrespective of area. In both market- and subsistence-oriented production systems, the culling of pigs affected pork availability, income generation and caused ecosystem disturbance in these crop-livestock systems. The same challenges were not witnessed in CSF-unaffected area under subsistence-oriented production system that was located on the coastal area. To facilitate restocking or conservation of local pig genetic resources, farmers requested the government to assist with loans, local pigs breeding stock, proper housing structure and improved extension services. Designing restocking programmes for pigs without taking into consideration the perceptions of the communal farmers is likely to cause passive resistance and prohibit co-operation by the communities. To better assist farmers recover from the devastating effects of CSF outbreak, it is essential to investigate the utilisation of local pigs under different communal production systems.

In Chapter 4, a survey was carried out to test the hypothesis that the utilisation of local pigs for rural development in subsistence- and market-oriented communal production systems of Southern Africa is similar. Local pigs were mainly used for income generation in the market-oriented production system while they were used for consumption in the subsistence-oriented production system. However, pig production was constrained by diseases and parasites challenges, feed shortages, inbreeding problems and abortions. All farmers acknowledged that climate had changed to hot conditions thereby limiting water and feed availability for pigs as was also reported by Gregory (2010). Socio-economic factors also determined pig production potential in both production systems. Households in subsistence-oriented production system were most likely to experience pig diseases, followed by heads of households who were not staying at home, uneducated people and old aged people because the level of management is low. Market-oriented households selected breeding stock based on performance traits such fast growth rate, desirable meat quality and litter in order to maximise profit (Chimonyo *et al*., 2010). Subsistence-oriented households' selection criteria were based on both productive and adaptive traits such as foraging ability to meet their multiple purpose function. Based on selection criteria, local pigs would be ideal for subsistence-oriented households and cross-breds with imported genotypes for market-oriented farmers. The findings of the current study could be useful in designing an appropriate restocking programme that considers the use of the much preferred and adapted local pig genotypes. Considering that climate has changed, it is important to be proactive by identifying pig genotypes that are heat tolerant and are likely to survive into the future.

A study was carried out in Chapter 5 to test the hypothesis that the heat tolerance mechanisms for South African local pigs and Large White pigs are similar. Superior heat tolerance of local pigs over LW pigs was related to lower heart rate, skin surface temperature, panting and frequency and duration behavioural heat loss activities such as wallowing, and sprawling in slurry and lying in a prostrate posture. These local pigs could be relevant in future breeding programmes as an intervention measure against climate change (Gregory, 2010). This intervention is particularly important for resource-limited communal farmers whose livelihoods are threatened by climate change. To better understand the impact of diurnal-related heat stress, the performance of pig genotypes in terms of ADFI, FCR and ADG needed to be evaluated. Such studies would generate useful information allowing farmers to assess potential loss in production due heat stress.

In Chapter 6 the hypothesis that was tested was that the growth performance of LW and South African local gilts under diurnal heat-related stress is similar. Under high ambient temperatures local pig genotypes performed better probably due to their heat tolerance as reported by Nengomasha (1997). The fact that high temperatures compromised average daily feed intake per kilogram metabolic body weight, average daily gain and feed conversion ratio for LW pigs implied that they are not adapted to hot conditions. The slow growth rate for local pigs was probably due to their inherent genetic make up (Chimonyo *et al*., 2005). The findings from the study could be used in designing crossbreeding programs with imported pigs to exploit breed complementarity and heterosis. These crossbreds would be ideal for commercial outdoor production systems where pigs' welfare is improved but pure imported pigs are unlikely to thrive. Evaluating heat tolerance of pig genotypes without attaching a monetary value to it and other breeding traits would not increase the economic value of local pig genetic resources. Establishing the total economic value of local pig genetic resources under different production systems helps to identify suitable candidates for the conservation of these important genetic resources.

The hypothesis that was tested in Chapter 7 was that farmer' preferences for pig traits in CSF-affected and unaffected areas under subsistence- and market-oriented communal production systems, and the implicit prices for these traits were similar. It was concluded that unfavourable adaptive traits such as feed purchase requirements and high frequency of sickness disadvantaged farmers in subsistence-oriented more than those in the market-oriented production system as was also reported by Roessler *et al*. (2008). Heat tolerance was, however, not selected for relative to other traits. Farmers in the market-oriented production systems derived more benefit from productive traits such as heavier slaughter weights and large litter size than subsistence-oriented farmers. Economic values for traits were high for subsistence-oriented production systems but could not be determined for the market-oriented production system because price was not significant. Outbreaks of major diseases like CSF (WOAH, 2005; Halimani *et al*., 2010) might have conscietised farmers about the importance of pigs' survival traits hence the willingness to pay higher prices for adaptive traits when compared to unaffected areas. The results suggest that subsistence-oriented communal farmers prefer adapted local pigs while the market-oriented farmers prefer high performing imported pig genotypes and their crosses with indigenous pigs. The findings provide the basis for policy makers in Southern Africa to promote the conservation of local pig genotypes under subsistence-oriented production systems.

8.2 Conclusions

More pigs were culled in coastal areas than inland areas and the risk of CSF disease outbreak was high in the former areas. The disease had equally devastating effects once there was an outbreak in an area. As part of the restocking efforts, there was higher potential for utilising adapted local pigs in developing subsistence-oriented production system and productive crosses of local pigs with imported genotypes in market-oriented production system. Local pigs had lower heart rate, skin surface temperature, panting and frequency and duration behavioural heat loss activities such as wallowing, and sprawling in slurry indicating that they have superior heat tolerance mechanisms over LW pigs. Under high ambient temperatures, local pigs also had a less compromised average feed intake per metabolic body weight, average daily gain and feed conversion ratio than LW pigs. Farmers in subsistence-oriented production systems selected pig breeding stock based on their adaptive traits when compared to market-oriented farmers who preferred productive traits. Subsistence-oriented farmers who were affected by CSF wanted a compensation price of R10 944.00 (USD1563.43) for keeping a pig genotype with unfavourable traits when compared to R4235.00 (USD605.00) for their CSF-unaffected counterparts. Implict prices for pig traits could not be determined under market-oriented production system.

8.3 Recommendations and further research

It can be advised that development agents in Southern Africa should encourage formation of pig cooperatives and fund these projects in communal production systems as a way of supporting restocking areas after major natural disasters that affect pig production like the CSF outbreak. Development agents should fund proper housing structures for these pig projects and assist farmers with sourcing breeding stock. Proper housing prevents pigs from roaming around and helps control the spread of diseases. The challenge is that farmers cannot afford to purchase feeds for confined pigs unless they are trained to run the projects commercially. Future disease outbreaks require that the government pay promptly market-related compensation for culled pigs so that farmers are not tempted to evade the control measures. Farmers must also be educated about the importance of culling in case of major disease outbreaks so that they cooperate and avoid further spread of the disease.

The Southern African governments should consider restocking CSF affected areas with local pigs and their crossbreds with imported pigs because they are adapted to the harsh environmental conditions prevailing in communal production systems. Development agents in Southern Africa should consider conservation programmes for local pigs so that farmers have access to breeding stock after major disease outbreaks in some areas. The adaptability of the local pig genetic resources to harsh tropical environment might be advantageous since climate is changing to hot conditions. It is recommended that farmers intervene during the hot summer conditions by spraying water on pigs to minimise the adverse effects of heat stress especially in imported pigs. Proper pig housing can shield pigs from direct sun and minimise heat stress. However, many people in communal production systems can not afford it considering the high level of poverty.

Aspects that require further research include the following:

1. Investigating the mechanisms underlying the superior heat tolerance response for local pigs. There is need investigate if local pigs release heat from their bodies through thermoregulatory windows arising from uneven distribution of subcutaneous fat.
2. Measurements of blood metabolites which indicate the actual level of stress in each local and imported pig genotypes could be done. Additional studies should focus on heat tolerance of crossbreds for indigenous and imported genotypes.
3. Further studies should determine the thermo-neutral zone for South African local pigs in order to have better understanding about their heat tolerance.
4. More research is required to determine growth curves and development patterns for different pig genotypes under direct sun conditions prevailing in free range rearing

systems during hot summer months. This information can help to estimate their appropriate ages and body weight at slaughter under such harsh conditions.

5. Further studies can assess the performance of South African local and imported pigs fed on high fiber diets. This is important considering that the change of climate to hot conditions also increases bush encroachment and favours fast growing plants that are rich in fibre. Pig genotypes that are better able to utilise these fibrous materials should be promoted in communal production systems.
6. Further research should characterize local pig genetic resources to aid selection, improvement through breeding and sustainable conservation programmes.
7. Further choice experiments can be carried out in other Southern African countries to establish the economic values of local pigs under market-oriented production system.

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Appendix I: Assessment of CSF effects and pig traits of economic importance in communal production systems of South Africa

University of Fort Hare
Together in Excellence

The objective of the survey is to determine the pig traits valued by resource-limited communal farmers and climate change effects on traits of economic importance.

Questionnaire number…………….. Enumerator name……………….
Municipality name………………… Community name……………….
Name of respondent……………….. Date…………………………….

A. HOUSEHOLD DEMOGRAPHY

A1. Head of the household
a. Sex M□ F□ **b. Marital status** Married□ Single□ Divorced□ Widowed□
c. Age <30□ 31-45□ 46-60□ >60□
d. Highest education level No formal education□ Grade1-7□ Grade8-12□ Tertiary□
A2. Principal occupation?..
A3. Religion? Christianity□ Traditional□ Moslem□ Other (specify)…….
A4. Is the head of the household resident on the farm? Yes □ No □
A5. What is the size of the household?

Age group	**Males**	**Females**
Adults (13+ years)		
Children (less than 13 years)		

A6. What role (s) does each family member play in pig production? (Tick one or more)

Role	**Adults**		**Children**		**Hired labour**
	Male	**Female**	**Boy**	**Girl**	
Feeding					
Penning pigs					
House construction and maintenance					
Mating management					
Health management					
Purchasing					
Slaughtering					
Selling					
Other (specify)					

A7. Are youths interested in pig rearing? Yes □ No □
A8. Explain your response?...
A9. How much land do you own (ha)?............ A**10. Arable (ha)**..............
A11. Is foraging communal? Yes□ No□
A12. If not, what is your land tenure system?..

A13. What crops did you grow in 2008/9 season? (Rank 1 as most commonly used crop for pigs)

Crop	**Rank**	**Area (ha)**	**Purpose of production**		
			Consumption	**Sale**	**Stockfeed**

A14. What type of livestock species do you keep? (Rank 1 as the most important specie)

Class	Cattle	Goats	Sheep	Pigs	Chickens	Other (specify)
Number						
Rank						

A15. How much income does your household get per month? R....................

A16. How many employed children do you have?..............................

A17. Wealth status of the household. Very poor □ Poor □ Less poor □

B. PIG HERD COMPOSITION, PURPOSES AND FUNCTIONS

B1. What is the composition of your pig herd?

Productive stage	**Breed**		
	Local	**Crossbred**	**Exotic**
Gilts			
Sows			
Boars			
Piglets			
Weaned female pigs			
Weaned male pigs			
Total			

B2. How did you acquire your pigs? Inherited□ Exchanged□ Bought□ Other (Specify)…

B3. Who is the owner of the pigs? Mother□ Father□ Children□ Other (specify)……

B4. If pigs were bought, where did you get the money to purchase them?

Bank (loan) □ Own capital □ Other (specify) ....

B5. Why do you keep pigs? (Tick one or more) (Rank 1 as the most preferred use)

Reason	**Tick appropriate response**	**Rank**
Selling to raise income		
Household consumption		
Savings and investment		
Manure		
Provision of fat		
Socio-cultural functions (e.g. lobola)		
Family pride and status		
Others (specify)		

B6. Indicate which factors affect pig production and rank them (1 being the major influencing factor)

Factor	Tick	Rank
Temperature		
Market access and integration		
Housing costs		
Feed costs		
Lack of credit and extension programmes		
Education level/ professional knowledge		
Prevalence of internal worms (*Ascaris suum*)		
Veterinary costs		
Other (Specify)		

B7. What is the production level at your household?

Parameter	Indigenous breed	Exotic breed	Mixed breed
Litter size at birth			
Litter size at weaning			
Age at weaning			
Pre-weaning mortality			
Weaning to mating period			
Number of pigs reaching market weight			
Age at puberty			
Number of farrowings per year			
Age at culling of boars			
Age at culling of sows			

C. FEEDING AND HOUSING MANAGEMENT

C1. Which pig production system are you using?

Scavenging	
Backyard	
Intensive	

C2. Do you change your production systems with seasons? Yes □ No □
C3. Do you provide supplementary feeding? Yes □ No □
C4. If yes, what feed materials are available for your pigs?

Season	Common feeds	Condition of pigs
Summer season		
Winter season		

C5. How much supplementary feed do you give a pig per day? ....kg/day
C6. Do you experience feed shortages? Yes □ No □
C7. If yes, how do you prioritise feeding during feed shortages?
…………………………………………………………………………...
C8. What is the source of drinking water for your pigs?...
C9. How often do your pigs drink water? ....
C10. Do you house your pigs at night? Yes □ No □
C11. If yes, what building materials do you use?……………………………………………

C12. Are piglets housed separately from adults? Yes □ No □
C13. If your pigs are not housed, how do they survive heavy rain, winter or frost conditions?
……………………………………………………………………………………

D. HEALTH MANAGEMENT

D1. Were your pigs culled as a result of classical swine fever? Yes □ No □
D2. If yes, how many pigs were culled?...
D3. If no, how did they survive the culling?...
D4. What is your perception about the disease?..
D5. How can it be controlled?...
D6. What could have been done differently by the government to handle the disease outbreak?..
D7. How much were you promised as slaughter value per sow? R.............................
D8. Did you receive your compensation? Yes □ No □
D9. Was the government compensation price satisfactory? Yes□ No □
D10. If not, how much should be ideal per sow? R..............................
D11. Does the pig price change as a result of major disease outbreak?
Increased □ Decreased □ No change □
D12. If prices have changed, give a reason…………………………………………………
D13. Are you satisfied with the government's efforts in pig restocking? Yes□ No □
D14. If not, give a reason ……………………………………………………………………
D15. Do you observe sows giving birth? Yes □ No □
D16. What is the cause of piglet mortality?

Cause	**Tick**	**Rank**
Cold		
Crushing		
Cannibalism		
Diseases		
Predators		
Other (specify)		

D17. Do you send dead pigs for post mortem? Yes □ No □
D18. Are there any incidences of abortion? Yes □ No □
D19. Do you have problems of internal worms (*Ascaris suum*) in pigs? Yes □ No □
D20. If yes, what are the effects of *Ascaris suum* on pigs?...
....
D21. Are your pigs tolerant or resistant to internal parasites? Yes □ No □
D22. What are the measures you take to curb *Ascaris suum*?..
....
D23. What are the other common pig diseases for your area?..
D24. How do you treat against diseases?

Traditional herbs	
Conventional drugs	
No treatment	
Others (specify)	

D25. Do any of your sows experience dystocia problems? Yes □ No □

D26. If yes, what measures do you take to curb the problem?..
....

E. MARKETING MANAGEMENT

E1. Do you sell your pigs? Yes □ No □
E2. If yes, on average how many pigs do you sell per year?..........................
E3. What are your major marketing channels?

Abattoir and supermarkets	
Informal markets (communities)	
Other (specify)	

E4. At what time of the year do you usually sell pigs and why? ……………………………..............
....
E5. What do you consider when pricing your pigs? Body condition □ Weight □ Age □ Class □ Breed □ Other (specify)...............
E6. What is the average weight of your pigs at 6 months?

Class of pigs	**Weight at 6 months**
Gilts	
Young boars	
Male castrate pigs	

E7. How do you sell your pigs? Live□ Fresh meat□ Other (specify)…………………
E7. Which breed do you prefer in terms of meat quality? Indigenous □ Exotic □ Cross □
E8. What makes the meat quality of the preferred breed superior?
Tender □ Fatness □ Taste □ Colour □ Juiceness □
E9. Which class of pigs do you usually sell?

Class	**Tick**	**Price**
Sows		
Boars		
Weaners		
Gilts		
Piglets		

E10. What other saleable products can be obtained from indigenous pigs?...............................
……………………………………………………………………………………………………
E11. What are these products used for?...

F. PIG BREEDING PRACTICES

F1. How do you obtain breeding pigs?

Buy from other farmers	
Selection within the herd	
Other (specify)	

F2. Have you noticed changes in your environment in the last 15 years? Yes □ No □
F3. If yes, which, and are there activities you cannot pursue anymore because of the change?...

F4. How did you adapt or change your activities?...
....
F5. Which climatic events had the major impact on your pig production in the last 15 years?
High temperatures□ Frost □ Floods□ Heat wave□
F6. Which breed do you think survives better under these extreme weather conditions?
Indigenous □ Exotic □ Crossbred □
F7. Are your pigs heat tolerant? Yes □ No □
F8. Do you think pig colour is important? Yes □ No □
F9. Give reason for your answer...
F10. How do you reduce mating of related pigs?
....
F11. What are the problems commonly associated with mating related pigs?

Indicator	**Tick**	**Rank**
Reduced mature size over generations		
Declining litter size		
Weak piglets		
Other (s)		

F12. Is mating controlled? Yes □ No □
F13. If yes, how is it controlled?...
F14. If not, how do you reduce inbreeding? ………………………………………………………
F15. Do you borrow the boar for mating? Yes □ No □
F16. If yes, how much do you pay for it? ....
F17. What is your boar to sow ratio?...
F18. Is mating and reproduction seasonal? Yes □ No □
F19. If yes, which season do pigs usually farrow?...
F20. Do you keep mating and birth records? Yes □ No □
F21. Do you think the government has done enough to conserve indigenous pigs? Yes □ No □
F22. Give reasons for your answer...
F23. Do you believe efforts should be put to conserving indigenous pigs? Yes □ No □
F24. Explain your response?..
F25. What are your reasons for preferring the main breed (s) you have? (Tick and rank 1 as the most preferred)

Attribute	**Exotic**	**Rank**	**Indigenous**	**Rank**	**Cross**	**Rank**
Fast growth						
Large litter sizes						
Quality of meat						
Low feed cost						
Resistant to diseases and parasites						
Foraging ability						
Good mothering ability						
Temperament						
Heat tolerance						
Body conformation						
Other (specify)						

Appendix II: Choice experiments for economic valuation of local pig genetic resources in South Africa

Objective

The objectives of this study were to determine farmer preferences for pig traits in CSF affected and unaffected areas under subsistence- and market-oriented production systems, and determine their willingness to pay for these traits.

Questionnaire number…………….. Enumerator name……………….

Municipality name………………… Community name……………….

Name of respondent……………….. Date…………………………….

A. DEMOGRAPHIC INFORMATION

1. Head of the household

a. Sex M□ F□ **b. Marital status** Married□ Single□ Divorced□ Widowed□

c. What is the age of the head of household? ……………… years

d. Highest education level No formal education□ Grade1-7□ Grade8-12□ Tertiary□

2. Principal occupation?..

3. Religion? Christianity□ Traditional□ Moslem□ Other (specify)…….

4. Is the head of the household resident on the farm? Yes □ No □

5. What is the size of the household?

Age group	Males	Females
Adults (13+ years)		
Children (less than 13 years)		

6. What is the importance of pigs? Very important □ Important □ Not important □

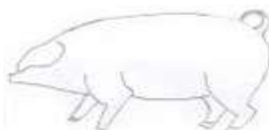
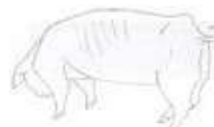
7. How much income do you get from pigs per annum? R....................

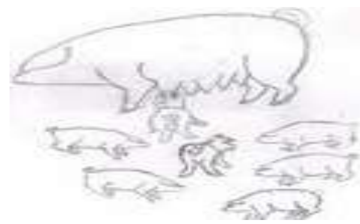
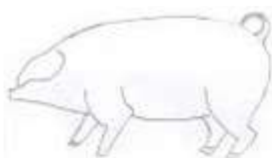
8. Do you consume pork? Yes □ No □

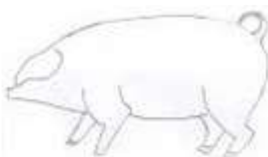
9. What is the wealth status of the farmer? Very poor □ Poor □ Less poor □

10. Who is the owner of the pigs? Mother□ Father□ Children□ Other (specify)……

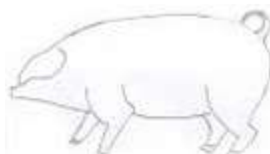
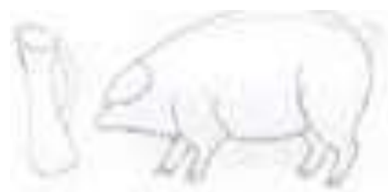
BLOCK 1 CHOICE SETS

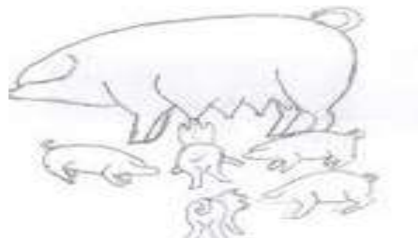
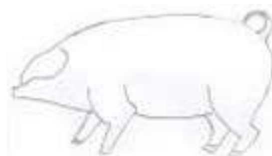
Card 1	Card 37	NoAnimal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: once/day 	**Watering frequency:** 3 times/day	
Live weight at 8 months: 60 kg	**Live weight at 8 months:** 80 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R800	**Sow price:** R1200	

Card 2	Card 38	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: 4-6 piglets 	**Litter size:** >6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	
Live weight at 8 months: 80 kg	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R1200	**Sow price:** R350	

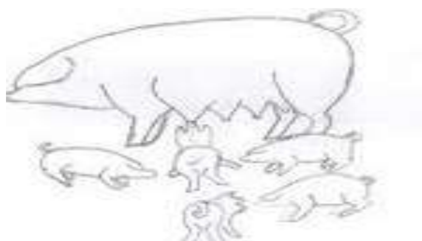
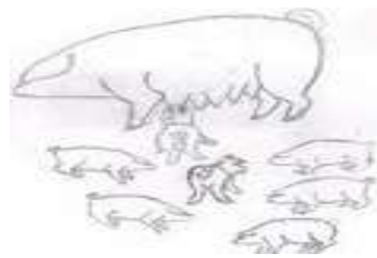
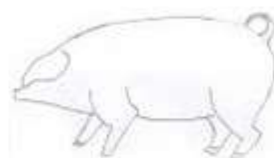
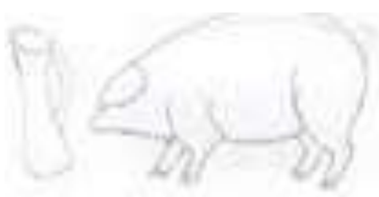
<table>
<tr><td>Card 3</td><td>Card 39</td><td>No Animal</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: > 6 piglets
</td><td>Litter size: 1-3 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 40 kg
</td><td>Live weight at 8 months: 60 kg
</td></tr>
<tr><td>Feed purchase requirements: No
</td><td>Feed purchase requirements: Yes

</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

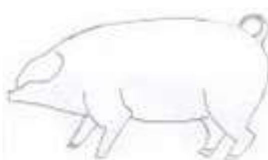
Card 4	Card 40	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	
Live weight at 8 months: 60 kg	**Live weight at 8 months:** 80 kg	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R1200	**Sow price:** R320	

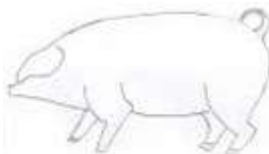
<table>
<tr><td>Card 5</td><td>Card 41</td><td>No Animal</td></tr>
<tr><td colspan="2" align="center">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 80 kg
</td><td>Live weight at 8 months: 40 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

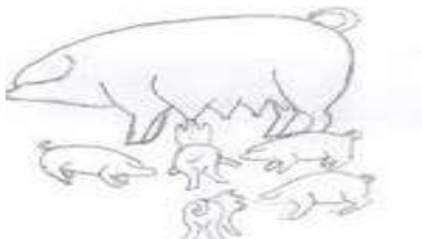
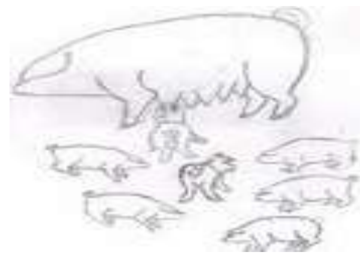
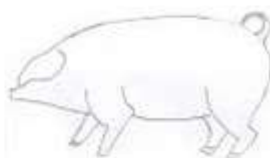
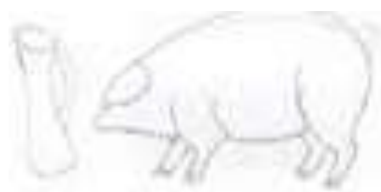
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

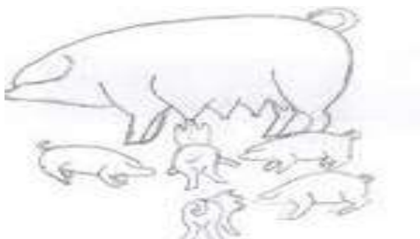
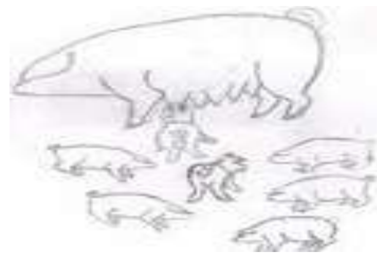
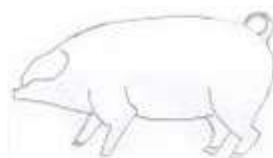
<table>
<tr><td>Card 6</td><td>Card 42</td><td>No Animal</td></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: once/day
</td><td>Watering frequency: thrice/day
</td></tr>
<tr><td>Live weight at 8 months: 40 kg
</td><td>Live weight at 8 months: 60 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R1200</td></tr>
</table>

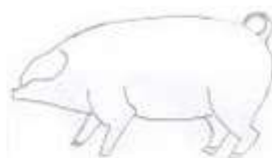
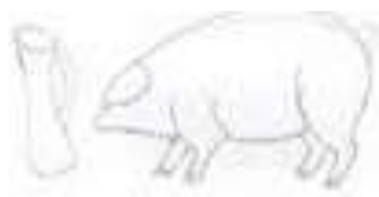
BLOCK 2 CHOICE SETS

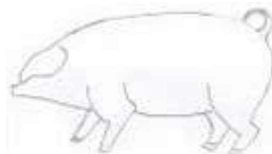
Card 7	**Card 43**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: thrice/day	**Watering frequency:** twice/day 	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R350	**Sow price:** R800	

Card 8	Card 44	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 60 kg	**Live weight at 8 months:** 80 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R800	**Sow price:** R1200	

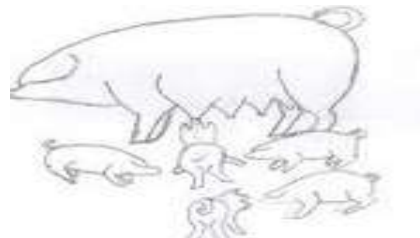
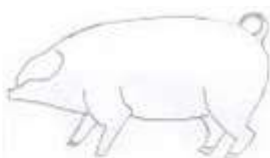
Card 9	**Card 45**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 4-6 piglets 	**Litter size:** > 6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	
Live weight at 8 months: 80 kg 	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R1200	**Sow price:** R350	

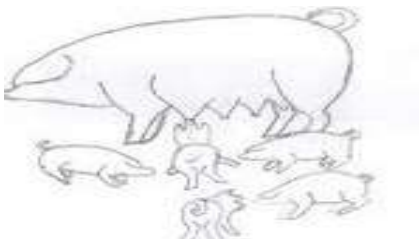
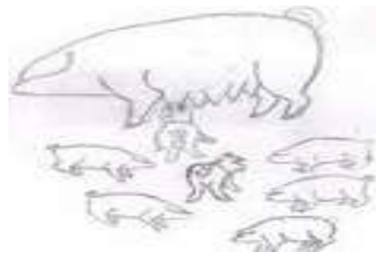
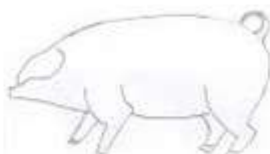
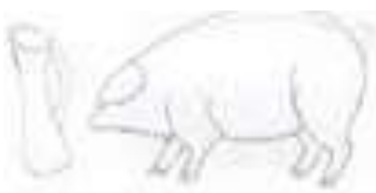
Card 10	**Card 46**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 4-6 piglets 	**Litter size:** > 6 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R800	**Sow price:** R1200	

Card 11	**Card 47**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	
Live weight at 8 months: 60 kg 	**Live weight at 8 months:** 80 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R1200	**Sow price:** R350	

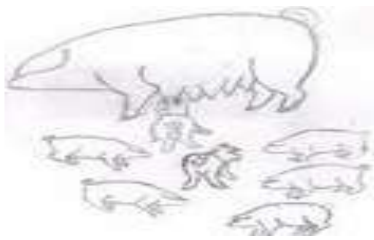
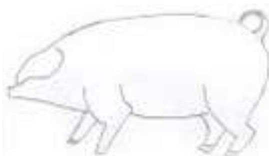
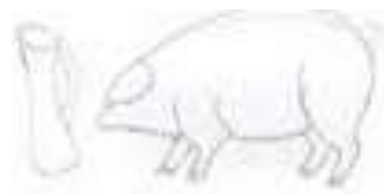
Card 12	**Card 48**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: thrice/day	**Watering frequency:** twice/day 	
Live weight at 8 months: 80 kg	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R350	**Sow price:** R800	

BLOCK 3 CHOICE SETS

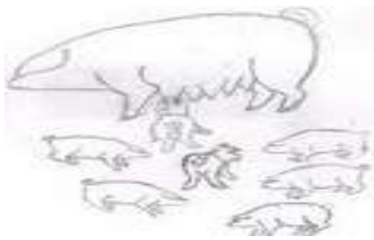
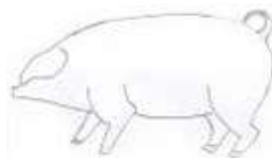
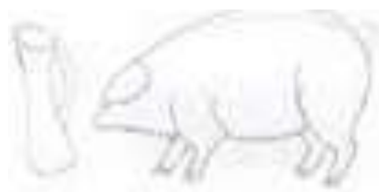
<table>
<tr><th>Card 13</th><th>Card 49</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 40 kg
</td><td>Live weight at 8 months: 60 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R1200</td><td>Sow price: R350</td></tr>
</table>

<table>
<tr><th>Card 14</th><th>Card 50</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: once/day
</td><td>Watering frequency: thrice/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

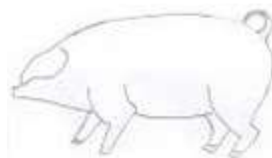
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

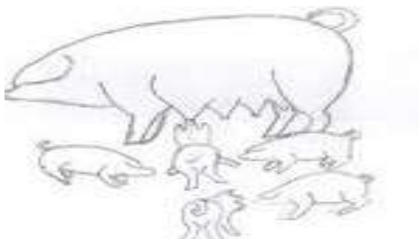
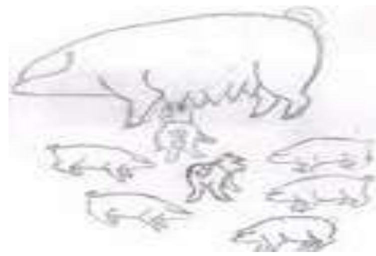
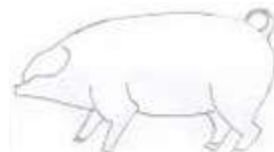
<table>
<tr><td>Card 15</td><td>Card 51</td><td>No Animal</td></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: > 6 piglets
</td><td>Litter size: 1-3 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 80 kg
</td><td>Live weight at 8 months: 40 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td></tr>
</table>

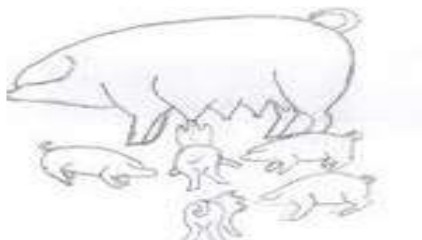
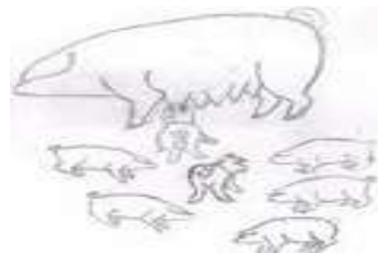
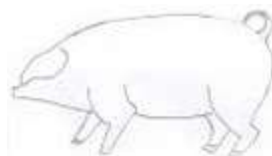
<table>
<tr><td>Card 16</td><td>Card 52</td><td>No Animal</td></tr>
<tr><td colspan="2" align="center">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: > 6 piglets
</td><td>Litter size: 1-3 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 80 kg
</td><td>Live weight at 8 months: 40 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

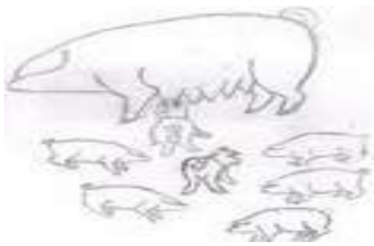
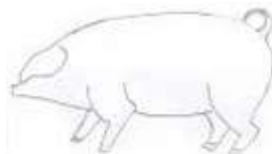
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td></tr>
</table>

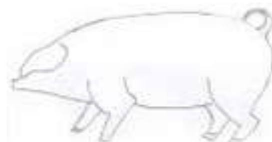
Card 17	Card 53	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: thrice/day 	**Watering frequency:** twice/day 	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg 	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R1200	**Sow price:** R350	

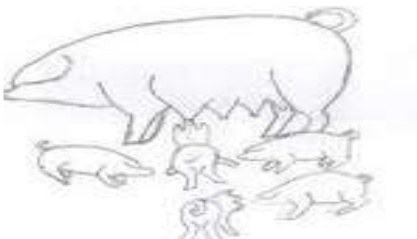
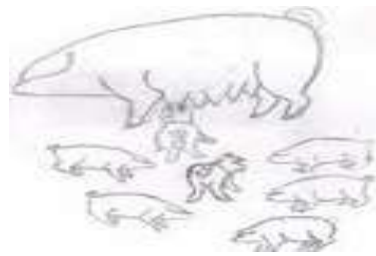
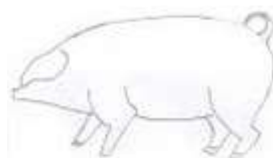
<table>
<tr><th>Card 18</th><th>Card 54</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="7">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: once/day
</td><td>Watering frequency: thrice/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td><td></td></tr>
</table>

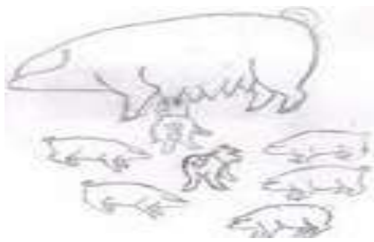
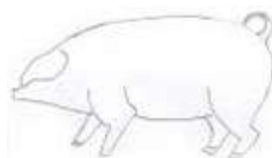
BLOCK 4 CHOICE SETS

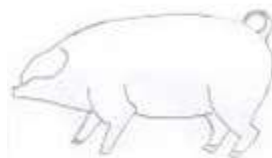
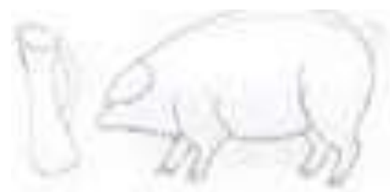
<table>
<tr><th>Card 19</th><th>Card 55</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 80 kg
</td><td>Live weight at 8 months: 40 kg
</td></tr>
<tr><td>Feed purchase requirements: No
</td><td>Feed purchase requirements: Yes
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td></tr>
</table>

Card 20	**Card 56**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R1200	**Sow price:** R350	

<table>
<tr><th>Card 21</th><th>Card 57</th><th>No Animal</th></tr>
<tr><td colspan="2" align="center">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: No
</td><td>Feed purchase requirements: Yes
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

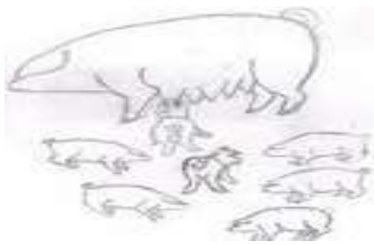
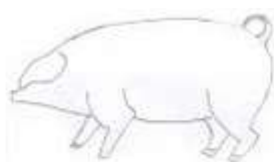
<table>
<tr><th>Card 22</th><th>Card 58</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="7">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R350</td><td></td></tr>
</table>

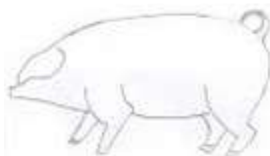
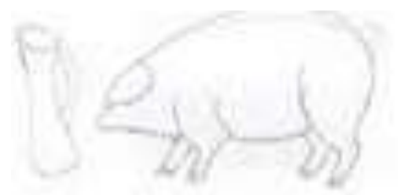
Card 23	Card 59	No Animal
A sow aged 12 months		Not buying the animal but keeping the money
Meat quality: high	**Meat quality:** low	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: once/day 	**Watering frequency:** thrice/day 	
Live weight at 8 months: 80 kg 	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R350	**Sow price:** R800	

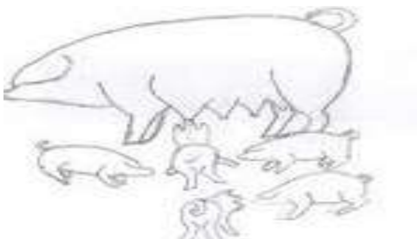
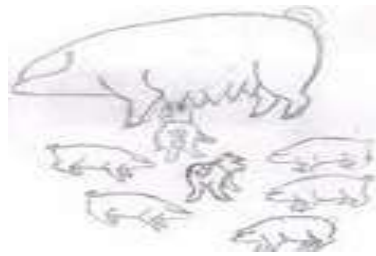
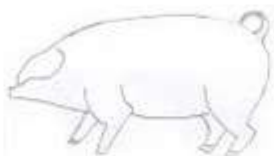
<table>
<tr><td>Card 24</td><td>Card 60</td><td>No Animal</td></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="7">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 40 kg
</td><td>Live weight at 8 months: 60 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

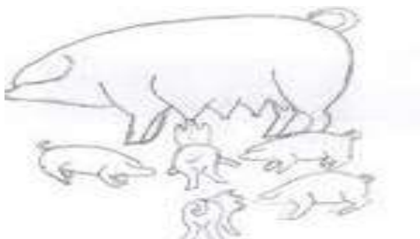
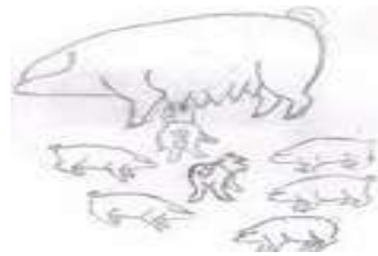
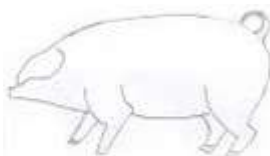
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td><td></td></tr>
</table>

BLOCK 5 CHOICE SETS

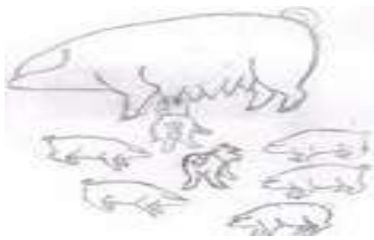
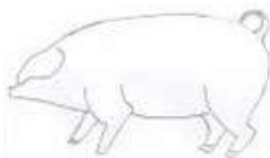
Card 25	**Card 61**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 80 kg	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R350	**Sow price:** R800	

Card 26	Card 62	No Animal
A sow aged 12 months		
Meat quality: low	**Meat quality:** high	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	**Not buying the animal but keeping the money**
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R800	**Sow price:** R1200	

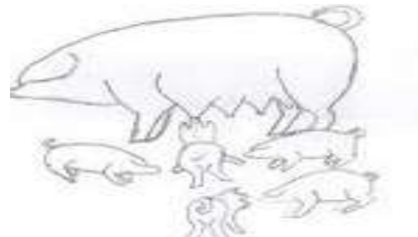
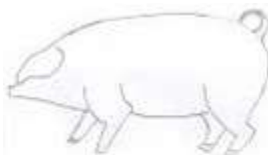
Card 27	**Card 63**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: 4-6 piglets 	**Litter size:** > 6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: thrice/day	**Watering frequency:** twice/day 	
Live weight at 8 months: 60 kg	**Live weight at 8 months:** 80 kg	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R1200	**Sow price:** R350	

<table>
<tr><th>Card 28</th><th>Card 64</th><th>No Animal</th></tr>
<tr><td colspan="2" align="center">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 4-6 piglets
</td><td>Litter size: > 6 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 40 kg
</td><td>Live weight at 8 months: 60 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

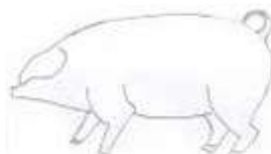
</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

<table>
<tr><th>Card 29</th><th>Card 65</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: > 6 piglets
</td><td>Litter size: 1-3 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: Yes

</td><td>Feed purchase requirements: No
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td></tr>
</table>

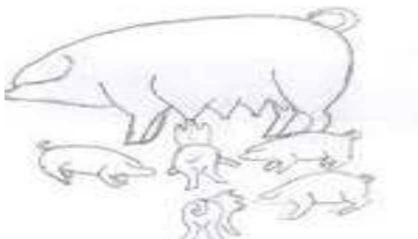
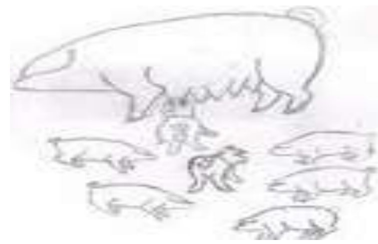
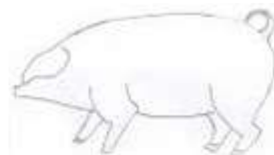
Card 30	Card 66	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 1-3 piglets 	**Litter size:** 4-6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 80 kg	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: Yes 	**Feed purchase requirements:** No 	
Sow price: R1200	**Sow price:** R350	

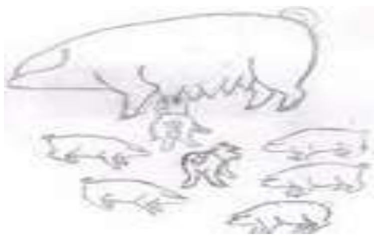
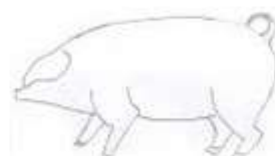
BLOCK 6 CHOICE SETS

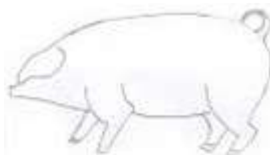
<table>
<tr><th>Card 31</th><th>Card 67</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: low</td><td>Meat quality: high</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: high
</td><td>Frequency of illness: rare
</td></tr>
<tr><td>Watering frequency: twice/day
</td><td>Watering frequency: once/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: No

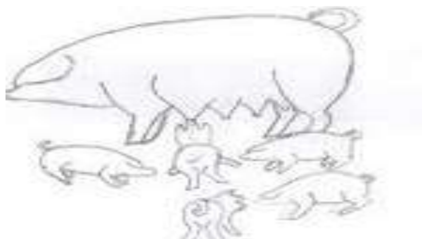
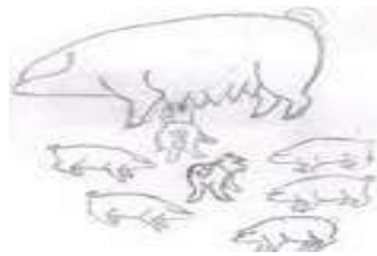
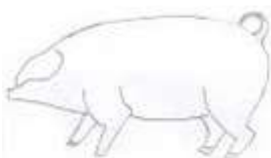
</td><td>Feed purchase requirements: Yes

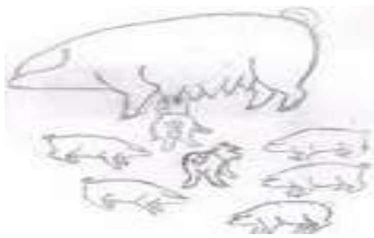
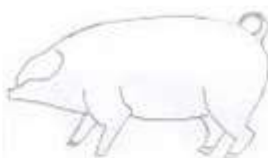
</td></tr>
<tr><td>Sow price: R350</td><td>Sow price: R800</td></tr>
</table>

Card 32	Card 68	No Animal
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: 4-6 piglets 	**Litter size:** > 6 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: thrice/day	**Watering frequency:** twice/day 	
Live weight at 8 months: 80 kg	**Live weight at 8 months:** 40 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R800	**Sow price:** R1200	

Card 33	**Card 69**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: low	**Meat quality:** high	
Litter size: > 6 piglets 	**Litter size:** 1-3 piglets 	
Frequency of illness: high 	**Frequency of illness:** rare 	
Watering frequency: once/day 	**Watering frequency:** thrice/day	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R1200	**Sow price:** R350	

<table>
<tr><th>Card 34</th><th>Card 70</th><th>No Animal</th></tr>
<tr><td colspan="2">A sow aged 12 months</td><td rowspan="8">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: 1-3 piglets
</td><td>Litter size: 4-6 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: once/day
</td><td>Watering frequency: thrice/day
</td></tr>
<tr><td>Live weight at 8 months: 80 kg
</td><td>Live weight at 8 months: 40 kg
</td></tr>
<tr><td>Feed purchase requirements: No
</td><td>Feed purchase requirements: Yes
</td></tr>
<tr><td>Sow price: R1200</td><td>Sow price: R350</td></tr>
</table>

Card 35	**Card 71**	**No Animal**
A sow aged 12 months		**Not buying the animal but keeping the money**
Meat quality: high	**Meat quality:** low	
Litter size: 4-6 piglets 	**Litter size:** > 6 piglets 	
Frequency of illness: rare 	**Frequency of illness:** high 	
Watering frequency: twice/day 	**Watering frequency:** once/day 	
Live weight at 8 months: 40 kg 	**Live weight at 8 months:** 60 kg 	
Feed purchase requirements: No 	**Feed purchase requirements:** Yes 	
Sow price: R350	**Sow price:** R800	

<table>
<tr><th>Card 36</th><th>Card 72</th><th>No Animal</th></tr>
<tr><td colspan="2" align="center">A sow aged 12 months</td><td rowspan="8" align="center">Not buying the animal but keeping the money</td></tr>
<tr><td>Meat quality: high</td><td>Meat quality: low</td></tr>
<tr><td>Litter size: > 6 piglets
</td><td>Litter size: 1-3 piglets
</td></tr>
<tr><td>Frequency of illness: rare
</td><td>Frequency of illness: high
</td></tr>
<tr><td>Watering frequency: thrice/day
</td><td>Watering frequency: twice/day
</td></tr>
<tr><td>Live weight at 8 months: 60 kg
</td><td>Live weight at 8 months: 80 kg
</td></tr>
<tr><td>Feed purchase requirements: No
</td><td>Feed purchase requirements: Yes
</td></tr>
<tr><td>Sow price: R800</td><td>Sow price: R1200</td></tr>
</table>

B. CHOICE EXPERIMENT FOLLOW-UP QUESTIONS

11. On a scale from 1 to 6, how would you rate your understanding of the choice questions?

6 = perfectly understood,
1 = not understood at all**.**
Tick one here

1	2	3	4	5	6

12. Across all choice questions, how important were the seven traits? Please rank them from 1 (most important) to 7 (least important) *Put the numbers 1 to 7 into the boxes*

- ☐ Meat quality
- ☐ Litter size
- ☐ Frequency of illness
- ☐ Watering frequency
- ☐ Live weight at 8 months
- ☐ Feed purchase requirements
- ☐ Sow price

13. Why have you decided to choose not to buy a pig in all choice questions? *Tick all that apply.*

- ☐ I cannot afford to buy at the moment
- ☐ All alternatives were dissatisfying.
- ☐ I did not understand the choice questions and was confused.
- ☐ I keep enough pigs at the moment/ I have reached the limit of keeping more
- ☐ I want to give up pig rearing and try to destock…
- ☐ Other reason (explain)…………………………………………………………..