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Production analysis of commercial and small holder pig farmers in the North West province of South Africa

by

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Declaration

I, Kayleigh Sarah Marcus, hereby declare that this dissertation, submitted for the MSc (Agric) Animal Science: Livestock Production degree at the University of Pretoria, is my own work and has not previous been submitted by me for a degree at any other institution.

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Abstract

There has been substantial growth in the small holder pig farming sector in South Africa. These farmers vary from market-orientated farmers to pig keepers with different available resources. There is a need to understand the requirements needed to close the gap between commercial and smallholder market-orientated farmers. There are limited scientific studies on the production and performance of smallholder pig farmers in South Africa. This study aimed to evaluate the production practices of smallholder pig farmers in the North west province using structured questionnaires. This study was conducted in two phases where firstly production data from six commercial farms representing small (<650 sows), medium (650 to 1200 sows) and large (>1200 sows) farms were analysed for production parameters; while phase two focused on smallholders in the North west province. In the commercial sector results indicated that small farms had a higher level of number born alive and piglet mortality due to being laid on by the sow (p-value <0.1). A significant difference was observed between farm sizes (small, medium and large) for number born alive in parities one, two, three, four, five, six, seven and eight (p-value <0.1). It was also found that there was a significant difference between the different sized farms for number of piglets weaned for parities one, four, seven and eight (p-value <0.1). Considering farm size for all production parameters, it was clear that management played an important role and large farms performed the best. Results from the 25 questionnaires indicated that the majority of the smallholder pig farmers utilized extensive pig housing most commonly built out of iron sheets, bricks and wire. Majority of the farmers were males and owned 0 to 20 sows, had 10 or less pigs in each production stage, had 1 or 2 boars and practices natural mating and the distance to the market was mainly 0 to 20km. The main constraints as stated by the farmers are lack of capital for housing, poor housing, high cost of feed, prevelence of diseases and hygiene and cost thereof. Stock theft was mentioned, while the areas for possible improvement were noted as genetics, housing and transport and management.

Table of Content

List of Abbreviations

SA	South Africa
ASF	African Swine Fever
ADG	Average daily gain
FCR	Feed conversion ratio
BCS	Body condition score
SLS	Second litter syndrome
MC	Maize cob
SH	Sunflower hulls
LH	Lucerne hay
CP	Dried citrus pulp
ADFI	Average daily feed intake
LD	Longissimus dorsi
EU	European Union
Ig	Immunoglobulin
MOLM	Moringa Oleifera leaf meal
WBSF	Warner Bratzler Shear Force
PUFA	Poly-unsaturated fatty acid
USA	United States of America
AI	Artifical insemintation
MH	Malignant Hyperthermia
PSS	Porcine Stress Syndrome
SNP	Single Nucleotide Polymorphism
DNA	Deoxyribonucleic acid
GEBV	Genomic estimated breeding value
PSSR	Porcine reproductive and respiratory syndrome
FMD	Foot and mouth disease
CSF	Classic swine fever
ASFV	African swine fever virus
NBA	Number born alive piglets
NSBP	Number of still born piglets
NMP	Number of mummified piglets
NPW	Number of piglets weaned
WWP	Weaning weight of piglets
NPS	Number of piglets slaughtered
SLAUW	Weight of piglets slaughtered
MORT	Prewean mortality
DRC	Democratic Republic of Congo
SAPPO	South African Pork Producers Organization
IQR	Inter-quartile range
SD	Standard deviation

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Introduction

The South African (SA) pork industry was established in the early sixties by making use of modern housing, feeding and breeding systems; and since then has developed into a fast-growing industry characterised by a well-developed highly intensive commercial pig sector, an emerging sector and informal pig keepers (FAO, 2019; Pienaar & Traub, 2015). The number of pigs slaughtered per annum in 1961 has increased from 1 000 000 to 2 961 000 in 2019; and the quantity of pig meat produced has increased by approximately 375% (FAO, 2019). In the last decade pork production has grown by 48% (BFAP,2020) and the quantity of pig meat produced is expected to increase by 11% by 2029 (BFAP, 2020) and a further 5% by 2030 (BFAP, 2021).

There are approximately 125 commercial pig producers and an estimated 4000 developing (market-orientated) pig farmers (Venter, 2019). Commercial producers are primarily situated in the Western Cape, Kwazulu-Natal, Gauteng and the Northwest provinces with commercial sow units varying between small (<650 sows) to medium (1 000-1 800 sows) to large (>1800 sows) producers, all applying various levels of technology with regard to housing (Knecht *et al.,* 2018), feeding (Bakare *et al.,* 2015) and breeding management (Ferguson & Kyriazis, 2003). The primary objective of informal pig keepers' is to feed their families whereas the market-orientated smallholder farmer also referred to as emerging farmers; lie anywhere between informal pig keeping and commercialized farms (Zantsi *et al.,* 2019). The informal herd in SA consists of approximately 893 000 pigs and is situated mainly in Eastern Cape and Limpopo with these provinces containing 46% and 13% of the national herd respectively (BFAP, 2020). The informal herd constitutes a total of 38% of the national herd, produces up to 26 500 tonnes annually and its production contributes approximately 10% of national production (BFAP, 2020). Scientific information on the informal sector is imperative because it provides an income and animal protein to the individuals living in the rural areas; this sector is valued at approximately R1.24 billion (BFAP, 2020).

The global pork meat production has decreased since 2018 from approximately 120 689 984 tonnes to 109 835 405 tonne in 2020 (FAO, 2019). Universally the most tonnes of meat produced was chicken followed by beef and then pork (FAO, 2019). The countries with the highest pork production are China, the European Union, the United States of America, Brazil and Russia with levels of 41.5 million, 24.5 million, 13 million, 4.2 million and 3.7 million metric tonnes respectively (Statista, 2021). In contrast to this, SA's pork production levels are approximately 279 400 tonnes and 25 000 tonnes are imported as well (FAO, 2019).

The per capita consumption of pork meat in SA in 2021 was estimated to be 4.3kg (BFAP, 2021) and makes up only 7% of the total meat consumed (USDA, 2017). In SA, pork is the least consumed meat due to the large number of people that due to religious beliefs cannot eat pork (DAFF, 2019; USDA, 2017). The market consists of porkers (the lean pigs, 55kg) which are sold as fresh meat while the heavier baconers (56 to 72kg) are sold for the processed market such as bacon or ham (USDA, 2017). Half of the meat produced by commercial farmers is used for processed meat and the other half is fresh meat that gets sold as pork (Venter, 2019). The SA pork industry provides 3015 jobs which includes commercial farms, abattoirs and factories for processing. The pork industry includes a number of important stakeholders such as breeders, farmers, abattoirs, processors, wholesalers, butcheries, retailers, importers and exporters and consumers whom which are all interconnected (DAFF, 2019).

Pig production in SA is regarded as vertically integrated (Davids *et al.,* 2014) with three major companies providing most of the genetics used in the industry, namely Topigs Norsvin SA Pty Ltd, Danbred Africa (Pty) Ltd and PIC South Africa. Breeding objectives focus on reproductive ability, robustness and welfare, feed efficiency and carcass quality (Topigs Norsvin Pty Ltd, 2022). This is done in order to have an efficient distribution of superior genes, for efficient production, to reduce feed costs and produce high quality pork (Topigs Norsvin Pty Ltd, 2022). Farmers use particular traits to measure the effectiveness of the production such as gestation period (114 days), lactation period (28-35 days), gilts mating age (30 to 31 weeks), gilt service weight (135 to 155kg), farrowing rate (90%), litters per sow per annum (2.38), total born alive per litter (13.5), post weaning mortality (2%), marketing age (22 to 24 weeks) and average carcass weight (75 to 80kg) (Personal communication Ms Senyatsi SAPPO, 2021). The breeds utilized by the genetic companies include Landrace, Large White, Duroc, Pietrain and formulated crosses (Danbred Africa (Pty) Ltd, 2022) in order to make optimal use of hybrid vigour (Visser, 2014).

In comparison to the commercial industry, the smallholder pig farmers face a variety of challenges with the main one being infrastructure. A lack of infrastructure includes the lack of transport, lack of roads, access to the market, electricity and water (Chaminuka *et al.,* 2008). In addition, the lack of funds, access to already existing commercial markets and having smaller herds creates barriers for these small but market-orientated farmers (Antwi & Seahlodi, 2011).

The management strategies used in smallholder systems differ to those used in the commercial setting. A study performed in Gauteng showed that 56% of the pig farmers had a high school education, 47% of the farms studied used liquid feed, 73% of farmers did not use a boar for breeding and 81% of farmers did not vaccinate their animals (Matabane et al., 2015). Either swill of leftover food in the kitchen is used as feed for the pigs but this leads to a diet that is unbalanced (Kagira *et al.,* 2010) which causes the pigs to gain fat very quickly (Madec *et al.,* 2010) as well as lowering the reproductive ability of the animal (Mokoele *et al.,* 2015). Smallholder farmers normally keep indigenous pigs in small numbers due to limited resources despite their ability to utilize root-crops and fibrous feed (Halimani *et al.,* 2010).

There is a lack of management and breeding routine, however, many of these farmers have started using exotic breeds such as the Landrace and Large White. In order to maximize the hybrid vigour, the farmers use cross between indigenous breeds such as the Kolbroek and an exotic breed such as the Landrace (Visser, 2014).

African Swine fever (ASF) is a major threat for all pig producers in SA. The disease is linked to the wildlife in South Africa and consequently cannot be eliminated; this has led to the imperative improvement of production management as well as biosecurity (Penrith *et al.,* 2013; Laanen *et al.,* 2013; Visser, 2014). ASF causes the infected animal to develop a fever as well as issues with its gastrointestinal tract and respiratory system (Gallardo *et al.,* 2015). These diseases affect the growing piglets and pigs however hypothermia and a lack of colostrum remain the main causes for the death of new born piglets (Shankar *et al.,* 2009, Mokoele *et al.,* 2015).

Besides ASF, a particularly common health issue for developing pig farmers are helminths. Helminths are responsible for 62% of the diseases found in the herds in smallholder systems (Nwafor, 2019). One of the diseases is endemic to Asia, Latin America and Sub-Saharan Africa, this disease is porcine cysticercosis and is caused by a particular species of helminth. This disease can be caused by insufficient sanitation, knowledge of the disease as well as management of their herd (Shongwe *et al.,* 2020). Pigs can contract this disease by ingesting Taenia eggs and when hatched; the brain, muscles and subcutaneous fat is infested. When humans ingest the eggs from contaminated pork meat they can be infected which can cause human cysticercosis (Sithole *et al.,* 2020).

The focus of the majority of the local SA research has been on the commercial pork industry and there is a dire need for research to provide solutions for the improvement of this developing sector; which is a fast-growing sector alongside the commercial production. As seen above; the pork industry is growing both internationally and locally; and growth in all sectors of the South African pork industry is required to meet these demands.

1.2 The aim of the study

SAPPO serves as the mouth piece for pig producers by connecting the pork producer with members of the organised agricultural sector. SAPPO's main aid for smallholder farmers is in the form of advice. This advice is given through mentorship programmes by which commercial producers and veterinarians provide advice on operations of the farm, veterinary matters and accounting advice (Personal communication Ms Senyatsi SAPPO, 2021). Furthermore, these smallholder farmers can also be enrolled in a training academy which teaches the smallholders about the basics and more in-depth practices required for pig production.

In order to conceptualize the disproportion between the production size of the highly developed and the smallholder producers; it is required to gather production information from the commercial producers and benchmark these levels.

The smallholder farmers in the North west province have no control over ASF and struggle to enter the commercial pork production industry; this emphasizes the need to further research their management practices, disease control as well as their marketing and selling practices to aid them in entering the pork value chain and contribute to food security.

The aim of the study is to gain insight on the management practices, production levels and incidence of disease of developing farmers in the North West province.

In order to achieve the aim, the following objectives were set:

1. To analyse fertility and growth data from commercial pig farmers (small, medium and large) for a benchmark based on commercial production.
2. Host information workshops with the small holder farmers and pig keepers (SAPPO) in the North West province and conduct a questionnaire collaboration with SAPPO staff.
3. To analyse the questionnaire data to propose suitable interventions for improving small holder pig production.

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Chapter 2

Literature review

2.1 Introduction

This literature review will address characteristics of commercial pork production such as housing, nutrition, genetics and the selection of economically important traits as well as biosecurity and disease prevention. Additionally, research conducted on the challenges that smallholder pig farmers in South Africa (SA) and other African countries experience will be discussed. These challenges include poor infrastructure, inaccesable nutrition, poor breeding and genetic conservation, socio-economic impact and lack of biosecurity and available disease prevention. The aspects discussed in both the commercial and smallholder sectors allows for a comparison of previous studies as well as the viewing of different production practices and resources of each sector. Moreover, this also emphasizes the vast majority of research focusing on the commercial industry and the dire need for further research of the smallholder farmers in order to better understand and aid them in their endeavours.

2.2 Production systems and primary factors determining profitability

2.2.1 Housing systems

There are certain factors which will determine a good housing system, namely: site selection, outlay of the house, insulation, ventilation, temperature, slurry and waste management and humidity (Visser, 2014). In Table 2.1 a summary is provided of the major aspects considered for intensive pig production.

Table 2.1 Some aspects considered for intensive pig production in naturally and environmentally controlled housing (Visser, 2014).

Housing system	Environmentally controlled	Mechanically controlled
Floor types	Concrete floors.	Slatted floors.
Ventilation	No use of mechanical equipment. Windows with curtain as well as a mono-pitched roof allows for air to flow through the house.	Ventilation is controlled by a variety of different roof pitches as well as cooling pads and/or fans.
Insulation	No insulation utilized within the walls. Curtains can be drawn over the window.	Insulation material to maintain the required temperature within the house.
Cooling vs heating systems	No mechanical equipment is in place.	Cooling is done with fans, mist sprayers or cooling pads or a mixture of methods. Heating completed using electricity, biogas, diesel or solar panels or a mixture of methods.
Water and slurry	Water is pumped using boreholes. Manure is collected manually.	Water from boreholes. Manure is removed using flush channels or shallow pits and utilized as fertilizer or converted into biogas.

In various literature the importance of ventilation and manure removal, floor type (Broucek, 2018) and insulation (Janse van Rensburg & Spencer, 2014, Knecht *et al.,* 2018) in pig housing have been reported. Gaseous nitrogen compounds, also known as greenhouse gases, cause extensive damage to the ozone through several processes (Broucek, 2018). The livestock industry contributes to 50% of the N_2O production (de Klein *et al.,* 2018) and in the pig industry N_2O is emitted only from the manure (Philippe & Nicks, 2014). Pig manure can be in either solid or slurry form and if 100% of the slurry produced is used as bio-fertilizer the intensity of emissions would be reduced 17 times more compared to if the slurry was not utilized (Mainali *et al.,* 2017). Studies have shown that emissions of N_2O were the highest in winter and lowest in summer (Broucek, 2018). Furthermore, nitrous compound emissions are higher (74%) in deep bedded systems compared to slatted floors (Rzeznik & Mielcarek, 2014) and sawdust litters to straw litters respectively (Nicks *et al.,* 2003). With regards to temperature control in pig housing, studies have shown that farrowing rate is greater (3%) when sows are mated at lower temperatures and number born alive increased as the environmental temperature increased (Janse van Rensburg & Spencer, 2014, Almond & Bilkei, 2005; Boma & Bilkei, 2006, Peltoniemi *et al.,* 2000). Despite deep litter being more welfare conscious for pigs (Morrison *et al.,* 2007); literature shows that slatted floors have a higher average daily gain (ADG) and final live weight with a lower feed conversion ratio (FCR) compared to deep litter floors by 73.52g, 5.83kg and 0.32kg/kg gain respectively.

A number of studies have been conducted on the effect of housing and feeding systems on efficient production. In a study to evaluate slatted floors, it was shown that pigs in the finishing stage with different genotypes had a higher final live weight, ADG and a lower FCR and mortality percentage (Knecht *et al.,* 2018). In contrast, finishers kept in a deep bedding system showed a lower backfat thickness, carcass weight, height of longissimus dorsi (LD) muscle, and a higher percent of lean meat (Knecht *et al.,* 2018).

Due to criticism by welfare groups on intensive pig production (Sather *et al.,* 1997); extensive pig production has expanded both locally and internationally with the herd size ranging from less than 10 sows to 10 000 sows (Honeyman, 2005). Extensive pig farming is classified as a system in which pigs are allowed to have access to the outdoors and be in contact with the natural ground and plants (Honeyman *et al.,* 2001) however this housing has a variety of possible options. Options include having all or only some of the pigs having access to the outdoors with the rest being housed on concrete or slatted floors; or an open sided barn that allows for access to the outdoors (Delsart *et al.,* 2020). The main advantage of extensive system is the pigs having more opportunity to express natural behaviour patterns (Hoffman *et al.,* 2003). Extensive systems face different challenges compared to intensive systems: the pig keepers have fewer automated tools therefore pig care is reliant on good husbandry skills and observation, it is harder to treat disease (Honeyman, 2005; Barton Gade, 2002), has a negative effect on the tenderness of meat (Sather *et al.,* 1997) and the growth of the pigs is slower (Hoffman *et al.,* 2003) compared to the conventional system.

Maintaining a good mental and physical health of animals (Carenzi & Verga, 2007) it what constitutes animal welfare and the five areas that can be influenced is movement allowance, social contact, the condition of the floors, climate and level of care (Scherer *et al.,* 2018). By providing sufficient nutrition, space for movement and shelter, prevention of disease and behavioural interaction the mental state of the animal will be improved (Kells, 2021). Majority of the conventional pig production systems are confined which do not allow pigs to perform their natural behaviours (Kells, 2021) which can lead to boredom, aggression and frustration (Mellor, 2014). It is possible to improve the time spent foraging and exploring with the addition of rooting material such as straw, peat, sawdust, hanging tyres and ropes and plastic toys (Godyń *et al.,* 2019). Products which are able to be chewed but not able to be broken or deformed as well as a mixture of materials provides the most exploratory behaviour in pigs (Godyń *et al.,* 2019; Ocepek *et al.,* 2020). Furthermore, human touch has been found to also decrease aggression, fear of people and stress in pigs during future interactions by embedding routine interactive time into the routine (Muns *et al.,* 2015).

2.2.2 Nutrition

Swine nutrition is a major area of research for enhancing commercial pig production and profitability. Different feeds are used for different stages of production such as piglets, weaners, growers, gilts, sows and boars. Phase feeding is described as feeding numerous diets in a specific period of time in order to meet the requirements of the animal as close as possible (Han *et al.,* 2000). This method of feeding is used in all stages of production but specifically in the grower-finisher stage of production and one to four diets are utilized (Montoro *et al.,* 2022). Feed efficiency and farm gas emissions are improved due to the diet being altered according to the pigs age and weight (Pomar *et al.,* 2014). Furthermore, properly feeding the growers and finishers allow for better growth and carcass characteristics such as increasing the lean meat percentage by 2 to 3% (Niemi *et al.,* 2010). Feeding correctly is imperative as this influences the animals' body condition score (BCS) (Montoro *et al.,* 2022) which is measured using a scale of 1 to 5 with one being thin, three being intermediate and five being fat (Charette *et al.,* 1996). Maintaining a suitable BCS is used as a measure for the females' reproductive performance as a low BCS will negatively influence all future litters (Thekkoot *et al.,* 2016). This can be seen with second litter syndrome (SLS) where sows following their first lactation, litter size decreases (Sell-Kubiak *et al.,* 2020) due to the loss of weight (Thaker & Bilkei, 2005).

Furthermore, investigation on the effect of inclusion levels of different fibrous materials on time spent on behavioural activities has been conducted (Bakare *et al.,* 2015). An increase in the inclusion levels of the fibrous materials such as dried citrus pulp (CP), maize cob (MC), Lucerne hay (LH) and sunflower hulls (SH) lead to a decrease in average daily feed intake (ADFI) and ADG but an increase in the time spent feeding (Bakare *et al.,* 2015). As the inclusion level of three of the sources of fibre (MC, SH, LH) increased the time spent drinking water increased and time spent lying down decreased. Studies conducted to determine the effect of liquid and dry feeding on different genotypes has shown that liquid feed results in a higher backfat thickness, carcass weight, height of longissimus dorsi (LD) muscle and lean meat percent (Knecht *et al.,* 2018).

Due to the high levels of antimicrobial resistance as well as the European Union (EU) prohibiting the use of antibiotic growth promotors since 2006; the need for finding an alternative beneficial options have increased. The alternatives being studied include probiotics, prebiotics, symbiotics and immunomodulators (Cholwińska *et al.,* 2020). Probiotics are defined as live micro-organisms which can benefit the health of the host when given in the correct amount (Ding *et al.,* 2021). The most common probiotics administered are *Lactococcus, Enterococccus, Bacillus* and yeast (Ding *et al.,* 2021). Probiotics increase the enzymes which allow for digestion and absorption of feed (Shin *et al.,* 2019; Singh *et al.,* 2019), inhibits the growth of pathogenic bacteria and prevents pathogens from adhesing to the digestive tract (Lambo *et al.,* 2021), improves immunity (Agazzi, 2015.), increases litter size and weight and reduces toxic gas emissions (Zhao & Kim, 2015). Probtiocs can be given orally – through feed or water – sprayed on the pasture or bed litter, intra-vaginally or with a faecal microbiota transplant (Lambo *et al.,* 2021).

Several studies have reported the effect of different probiotics on growth, blood parameters and the production of antibodies (Loljanica *et al.,* 2010; Vrotniakiene & Jatkauska, 2013). It was found that the use of probiotics had no effect on feed intake (FI) however, there was a significant difference in average daily gain (ADG) levels as well as a 30% increase of efficiency when a combination of probiotics was utilized (Dlamini *et al.,* 2017). Furthermore, it was found that probiotics reduce clinical signs of diseases of udder and/or uterus, reduces the weaning-to-oestrus interval, improvement of colostrum quality as well as milk quality and quantity; and increases litter size and the growth rate of the piglets when probiotics are fed to the sow (Alexopoulos *et al.,* 2004). When probiotics are fed to piglets they help stabilize the microbiome of the gut, protect against diarrhoea, cell count for pathogenic bacteria decreases and immunoglobulin (IgG) levels were improved (Ding *et al.,* 2021; Zhu *et al.,* 2014). Therefore, probiotics seem to hold the potential to increase gut health and overall immunity of pigs (Ding *et al.,* 2021; Agazzi, 2015).

Plant alternative such as *Moringa oleifera* leaves have been studied indicating the addition of the meal (MOLM) at a 7.5% inclusion resulted in a significantly higher average daily feed intake (ADFI) (Mukumbo *et al.,* 2014; Su & Chen, 2020). The addition of MOLM did not affect the recorded slaughter weight or any carcass characteristics (Mukumbo et a., 2014; Zanu *et al.,* 2012). Moreover, there was no difference between treatments for the pH level at 24 hours post slaughter, lightness, redness or yellowness of the meat, the cooking loss, thawing loss, and Warner Bratzler Shear Force (WBSF) records (Mukumbo *et al.,* 2014). Colour change and odour formation was noted on day seven with higher prevalence and noticeability with inclusion levels of 5% (Su & Chen, 2020); no significant differences in levels of subcutaneous fat however; the inclusion of MOLM influenced the levels of stearic acid (Mukumbo *et al.,* 2014). Furthermore, the treatments containing MOLM had increased levels of poly unsaturated fatty acids (PUFA) (Su & Chen, 2020) and improved n-6: n-3 ratios (Mukumbo *et al.,* 2014).

Duckweed has been studied for use in pig diets (Gwaze & Mwale, 2015; Nguyen, 1998; Rodriguez & Preston, 1996) as it contains the levels of methionine and lysine that are required for pig production, minerals, vitamins and lipids required for bodily functions (Men *et al.,* 1995) and despite when grown in media with poor nutrient, the level of nutrients does not diminish (Kesaano, 2011; Mwale & Gwaze, 2013). The drying process before being utilized can be done by using the sun (Akter *et al.,* 2011), oven, parboiling, air drying or pressing (Gwaze & Mwale, 2015). Literature investigate the use of various inclusion levels of duckweed and it was found that a 40% inclusion resulted in an improvement of feed efficiency, at 50% inclusion sows had heavier and larger litters as well as a higher rate of survival (Men *et al.,* 1995); while 60% inclusion had a negative effect on feed efficiency. Furthermore, duckweed has been reported to be more readily accepted by indigenous piglets compared to Large White due to palatability and digestibility (Nguyen, 1998; Rodriguez & Preston, 1996).

Recent research in pig nutrition has a major focus on the understanding the pig gut and the microbiome within (McCormack *et al.,* 2017; Fouhse *et al.,* 2016; Dou *et al.,* 2017; Li *et al.,* 2017). Several studies have shown a positive influence on nutrient metabolism, controlling the immune system and protecting against pathogens (McCormack *et al.,* 2017; Fouhse *et al.,* 2016). Furthermore, studies have also shown that piglets with post-weaning diarrhoea have a specific gut microbiome (Dou *et al.,* 2017) and the use of antibiotics during the piglets' early life blights the development of the gut microbiome which will carry through the pigs' lifetime (Li *et al.,* 2017). Provotella is one of the most common genera found in the gastro-intestinal tract (GIT) (Holman *et al.,* 2017) and positively influences feed intake (Yang *et al.,* 2018), feed efficiency (Ramayo-Caldas *et al.,* 2016), diarrhoea (Dou *et al.,* 2017) and weight gain (Mach *et al.,* 2015). With the increasing use and decreasing price to use meta-omics; it will be possible to characterize the composition and metabolic activities of more complex microbiomes (Zhang *et al.,* 2019) as well as further studying of the pig GIT microbiota. In Table 2.2 a selected number of studies on pig diets, gut microbiome as well as alternative feeding additives that improve production has been summarized.

Table 2.2 A selected number of studies on pig appetite, gut microbiome and alternative feeds.

Topic	References
Appetite	Bakare *et al.,* 2015; Knecht *et al.,* 2018
Gut microbiome	Dou *et al.,* 2017; Mach *et al.,* 2015; McCormack *et al.,* 2017; Ramayo-Caldas *et al.,* 2017; Yang *et al.,* 2018.
Alternative feeds	Gwaze & Mwale, 2015; Men *et al.,* 1995; Mukumbo *et al.,* 2014; Nguyen, 1998; Rodriguez & Preston, 1996; Su & Chen, 2020.
Probiotics	Agazzi, 2015; Dlamini *et al.,* 2017; Lambo *et al.,* 2021; Loljanica *et al.,* 2010; Shin *et al.,* 2019; Singh *et al.,* 2019; Vrotniakiene & Jatkauska, 2013.

An in depth review of pig nutrition was beyond the scope of this study, but it is clear from the literature how a vast amount of studies has been conducted and that new feeding methods and feed additives are continuously being studied (Lambo *et al.,* 2021; Yang *et al.,* 2018).

2.2.3 Genetics and selection of traits of economic importance

Modern pig producers have been using breeding schemes which comprise of a nucleus herd, multiplier and commercial herds (Knox, 2016; Visscher *et al.,* 2000). The nucleus herd consists of purebred (great grandparents) maternal breeds (Landrace and Large White) which are bred to create crossbred F_1 females (grandparents) for the multiplier herd (Knox, 2015; Visscher *et al.,* 2000). These breeds are known as maternal breeds as they have a higher reproductive performance (Visscher *et al.,* 2000).These F_1 females are then mated to purebred or crossbred sires to produce commerical sows (parents) (Knox, 2016: Visscher *et al.,* 2000) (Figure 2.1). The breeds utilized for terminal sires have a greater performance in growth and carcass traits (Visscher *et al.,* 2000). These commercial sows are then mated with a sire to produce piglets to be sold to the market (Knox, 2016; Visscher *et al.,* 2000). The nucleus and multiplier herds are closed and therefore a proportion of the sows produced must be used as replacement gilts which can increase the level of inbreeding (Knox, 2016; Visscher *et al.,* 2000).

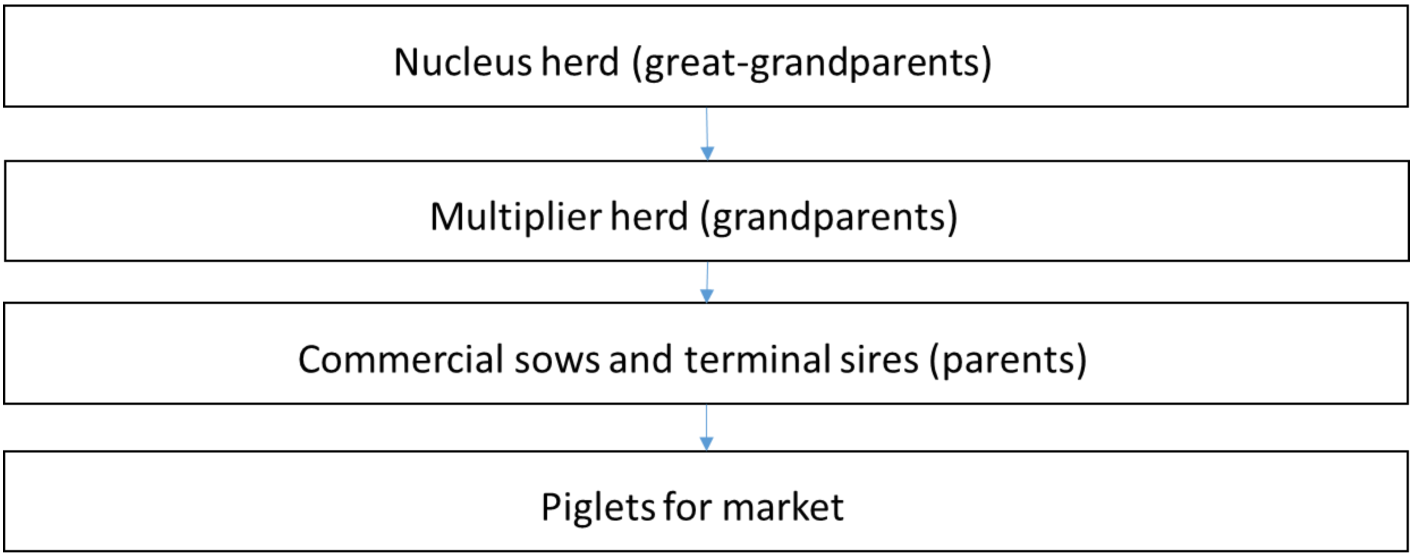

Figure 2.1 The breeding scheme used in modern commercial pig production adapted from Knox, 2015)

Through the use of genetics, production levels internationally have significantly increased showing an avergage of 18 piglets born alive per litter per sow, 1.9 piglets still born per litter per sow (Personal communiction with Ms Norval at Danbred Denmark with email address asno@danbred.com). Furthermore, statistics show high numbers of weaned piglets per sow per litter in 2020 in 18 different countries such as: Austria (11.24), Belgium (13.40), Mato Grosso region in Brazil (11.87), Santa Catarina region in Brazil (12.44), Canada (11.01), Denmark (15.06) (Personal communiction with Ms Norval at Danbred Denmark with email address asno@danbred.com), Finland (13.16), France (12.69), Germany (13.32), intensive pig production in Great Britain (12.19), free-range pig production in Great Britain (10.96), Hungary (13.36), Ireland (12.68), Italy (11.39), Netherlands (13.17), Spain (12.23), Sweden (12.42) and the United States of America (USA) (11.37) (AHDB, 2021).

In the commercial pork industry breeding is done mainly with the use of artificial insemination (AI) (Knox, 2016; Crabo & Dial, 1992; Visscher *et al.,* 2000). Through the development of AI, it was found that boar sperm survival and overall fertility are decreased when cryopreservation is utilized and therefore pig semen is preserved in liquid form (Johnson *et al.,* 2000). Therefore, the use of AI in pigs focused on preservation in liquid form (Waberski *et al.,* 2019). The main advantages of using AI is hastening the rate of genetic improvement, reduction of veneral diseases (Maes *et al.,* 2008; Crabo & Dial, 1992) and being able to use a single boar ejaculate for 10-20 sows (Knox, 2016). This modern technology can be utilized to safely bring in new genetics to herd and control inbreeding (Crabo & Dial, 1992). The use of AI is also designed in order to utilize crossbreeding and maximise heterosis (Knox, 2016). Heterosis occurs in the offspring with phenotypic superiority over the two parents with respect to specific traits – such as growth and reproduction (Lippman & Zamir, 2007).

As in most farm animals, the heritability for fertility traits tend to be low while, growth and carcass traits vary from moderate to high (Table 2.3).

Table 2.3 Selected studies reporting traits of economic importance.

Traits	Heritability range	References
Number of piglets born alive	0.06-0.23	Dube *et al.,* 2012; Lee *et al.,* 2015; Zak *et al.,* 2017; Ogawa *et al.,* 2022
Litter weight at birth	0.11 - 017	Dube *et al.,* 2012; Zak *et al.,* 2017; Ogawa *et al.,* 2022
21 day litter weight	0.06-0.17	Dube *et al.,* 2012; Ogawa *et al.,* 2022
21 day litter size	0.1-0.3	Dube *et al.,* 2012; Ogawa *et al.,* 2022
Average daily gain	0.15-0.5	Chimonyo & Dzama, 2007; Fu *et al.,* 2021; Homma *et al.,* 2021; Ogawa *et al.,* 2022
Feed conversion ratio	0.11-0.32	Fu *et al.,* 2021; Homma *et al.,* 2021
Back fat (P2) thickness	0.63	Lee *et al.,* 2015; Ogawa *et al.,* 2022

Genetic research has confirmed the presence of the malignant hyperthermia (MH) gene on chromosome six which is responsible porcine stress syndrome (PSS); this defect's symptoms include shortness of breath, increase in body temperature, collapse and death followed by immediate rigor mortis (Ball & Johnson, 1993). The original test utilized for the identification of carriers involved the pigs having to inhale halothane gas (Basic *et al.,* 1997). The test now used in modern pig production was discovered in the 1990s which allowed for the identification of non-carriers, carriers and animals with the mutation (Monin *et al.,* 1999; Wendt *et al.,* 2000). This research has aided international breeding companies to select against the gene and control the presence through informed mating (Monin *et al.,* 1999; Wendt *et al.,* 2000; Visscher *et al.,* 2000). Literature has also been conducted with the aim to identify genomic regions associated with thermo-tolerance traits in gilts (Kim *et al.,* 2018) and is summarized in Table 2.4 below.

Table 2.4 Genomic regions associated with thermo-tolerance regulation in gilts (Kim *et al.,* 2018)

Thermo-tolerance trait	Associated gene
Respiration rate	Growth hormone receptor (GHR) Poly(A) binding protein inter-acting protein (PAIP1) Nicotinamide transhydrogenase (NNT)
Skin temperature	ERB-B2 receptor tyrosine kinase 4(ERBB4) FK506 binding protein (FKBP1B) Nuclear factor of activated T-cells 2 (NCFATC2)

The sequencing of the pig genome has allowed for the characterization of various pig breeds and genome wide association studies to search for genes associated with growth, fertility, disease, feed converion and behaviour traits (Hu *et al.,* 2016). During the past fourteen years single-nucleotide polymorphisms (SNPs) have been utilized on a large scale for genotyping many DNA markers simultaneously in various livestock species (Nonneman & Lents, 2022). Due to the SNP arrays providing concentrated coverage of the genome, associations between traits and segments of DNA have been investigated and are of importance to the breeding companies (Nonneman & Lents, 2022). SNPs has allowed for the development of genomic estimated breeding values (GEBVs) (Boichard *et al.,* 2016). The use of a GEBV allows for early determination of potential and removal of progeny testing therefore lowering the costs of production (Boichard *et al.,* 2016). Literature shows that GEBV has been used to predict traits such as reproduction, fatness, meat and growth traits (Melnikova *et al.,* 2021).

The Kolbroek – a South African indigenous breed's genome has not yet been sequenced. The production levels of this breed remain low compared to their exotic counterparts the Landrace, Large White, Pietrain and Duroc which are commonly used in the commercial sector (Lipendele *et al.,* 2015). This highly under-researched breed is kept by pig keepers in SA but the emerging market-orientated smallholder farmers are using the exotic breeds such as the Landrace or Large white (Munzhelele *et al.,* 2017).

2.2.4 Biosecurity and disease prevention

Biosecurity is defined as measures implemented to prevent the induction and spread of disease (Pritchard *et al.,* 2005). Research has confirmed that production performance increases with correctly implemented biosecurity measures and; is often implemented at a higher rate on farms with large herds with modern technology (Laanen *et al.,* 2013). Biosecurity is important to implement as it is known to prevent the entry and spread of Porcine Reproductive and Respiratory Syndrome (PRRS), Classic Swine Fever (CSF), Foot and Mouth Disease (FMD) and African Swine Fever (ASF) (Visser, 2014). The most common pathogenic bacteria to affect humans include *Salmonella spp, Campylobacter spp, Staphylococcus spp, Listeria monocytogenes, Closridium perfringens, Clostridium botulism* together with two strains of *E. coli* (*Tanih et al., 2015*) and these harmful bacteria can be controlled and prevented from spreading with the use of biosecurity. In addition of the use of biosecurity to prevent the spread of disease; antibiotics are also over- and misused and this can cause drug resistance (Tanih *et al.,* 2015, Sithole *et al.,* 2021).

Local research was conducted to determine the presence of pathogenic *E. coli* and *Staphylococcus aureus* that can be detrimental to humans (Tanih *et al.,* 2015). Out of the 176 samples taken 87.5% of which had the presence of at least one bacterial species. *E. coli* and *S.aureus* were found in the highest percentages of 67.5% and 48.1% respectively; with pork having a greater bacterial presence compared to beef (Tanih *et al.,* 2015). Microbial resistance was tested against various antimicrobial medications and it was found that against bacitracin and vancomycin, oxacillin, erythromycin and streptomycin*; E. coli* had 100%, 98%, 92% and 5.7% resistance respectively (Tanih *et al.,* 2015).

Campylobacter spp (zoonotic disease) are prevalent in the gastrointestinal tract (Karikari *et al.,* 2017) in all livestock especially and is the main cause for gastroenteritis but specifically campylobacteriosis (Sithole *et al.,* 2021). The three most common subspecies are *Campylobacter jejuni (C. jejuni), Campylobacter lari (C. lari)* and *Campylobacter coli (C. coli)* (Sithole *et al.,* 2021). A study based on samples from piglet stage up to the holding pens at slaughter indicated that 72% of the samples along the production chain were contaminated with *Campylobacter spp* (Sithole *et al.,* 2021). The samples taken in the first week when the piglets were first put into the pen indicated no contamination however, in the fourth week *C. jejuni* contamination was found (Sithole *et al.,* 2021). The most common strain in the transport and holding pens was *C. coli* (17%), and in retail *C.jejuni* was found in the highest concentration (17.6%). The highest level of drug resistance was against erythromycin with *C.coli* and *C. jejuni* with 89% and 99% respectively. In addition, multidrug resistance was found in 87.3% of the contaminated samples (Sithole *et al.,* 2021).

Salmonella is one of the main causes of foodborne diseases globally and is related mainly to food as food can be a form of transmission (Mürmann *et al.,* 2009). Problems with salmonella are caused mainly by management issues and is contained by controlling the source of contamination and the transmission (Mathole *et al.,* 2017). A local study has found that pigs had the highest level of Salmonella contamination with 5.9% compared to other livestock species. Furthermore, subspecies of Salmonella found include *S. schwarzengrund, S. Aarhus, S. pomona, S. senftenberg* and *S. techimani* (Mathole *et al.,* 2017).

The diseases prevalent to the commercial producers are not only predominant in smallholder farming but also a main challenge for improved production in this sector.

2.3 The Smallholder Pig Production in South Africa

In South Africa the term ‘smallholder’ includes a spectrum of farmers from subsistence farmers to market-orientated smallholder farmers. The two main differences between the two ends of the spectrum is the size of their production and their reasons for farming (Zantsi *et al.,* 2019). Subsistence farmers farm in order to provide food for their family whereas the commercially orientated smallholders’ farms in order to sell their product (Zantsi *et al.,* 2019). The market-orientated or emerging farmers lie between the subsistence and commercially orientated smallholder; these farmers sell their product however desire to commercialise their production (Zantsi *et al.,* 2019). Defining smallholder farmers is important as it will allow for the enhancement of designing help programmes, knowing under which group the smallholders fall will allow for more comprehensive budgeting (Zantsi *et al.,* 2019).

Understanding smallholders and their importance is imperative due to the fact that smallholders can aid in poverty reduction (Diao *et al.,* 2010; Penrith *et al.,* 2013, Halimani *et al.,* 2010; Matabane *et al.,* 2015), creating job opportunities (Mmbengwa et al, 2015, Halimani *et al.,* 2010; Matabane *et al.,* 2015), improving the services offered to developing farmers (Zantsi *et al.,* 2019) and it provides food for the farmers’ family (Penrith *et al.,* 2013). In terms of creating job opportunities, the commercial industry uses more machinery whereas the smallholder industry uses more labour. This together with the fact that there are more smallholder farmers than commercial farmers mean that more individuals will be provided jobs (Zantsi *et al.,* 2019). Improving the services offered to developing farmers will be due to understanding the person requiring help; leads to a more precise service (Zantsi *et al.,* 2019).

Income and turnover are not applicable for the assessment of small farmers due to different studies find vastly different results (Aliber & Hart, 2009) as well the fact that different livestock sectors will have contrasting structural elements such as the dairy industry and extensive sheep farming (Zantsi *et al.,* 2019; Mutua *et al.,* 2010). The main reason for farming is the main indictor used as it will differentiate between an individual that is only wanting to provide food security for their family or wanting to increase their income (Zantsi *et al.,* 2019).

However, despite the research done to aid the smallholder farmers', they still face a variety of challenges including inadequate feeds, inadequate housing, parasites and disease, no access to the market, no management skills and no support from organizations (Halimani *et al.,* 2012; Adeyotse & Silas, 2020). Small holder farmers are often subjected to different socio-economic conditions compared to commercial producers. Factors such as culture and gender and age may play a role in the farming operation and ownership. There has been varying results in local studies conducted about which gender operates majority of smallholder pig farms. (Munzhelele *et al.,* 2017; Halimani *et al.,* 2012) Furthermore, a local study found that 54% of the smallholder farmers were above the age of 50 years old and more than 75% of the participants were classed as poor or below average in terms of economic status (Munzhelele *et al.,* 2017). A survey conducted in the Chiumhanzu district in Zimbabwe (78) and Vhembe (99), OR Tambo and Alfred Nzo (22) in SA found that farmers owned a variety of livestock and very few farmers owned boars (Halimani *et al.,* 2012). Furthermore, 68% of the farmers preferred to keep – and kept – indigenous pigs while only 5% kept exotic breeds (Halimani *et al.,* 2012).

A SA study conducted found that previously disadvantaged black South Africans (98.6%) made up majority of the smallholder pig farmers, of which less than 10% have a university degree, only 19.6% have received training in the agricultural sector and merely 33% have received financial aid (Munzhelele *et al.,* 2017). The breeds that are kept by these smallholder farmers consist of mainly exotic breeds such as the Landrace and Large White (89%), 75% of these farmers exhibited perilous decisions such as using auction sourced boars, untested boars from neighbours and free-range boars which can lead to the spread of disease (Munzhelele *et al.,* 2017). Furthermore, only 0.5% fed the pigs ad lib, 83% do not vaccinate their animals and only 10% using recording methods. The main causes for pre-weaning mortalities were the crushing of piglets by the sow, the piglets being born weak; neonatal diseases, poor management knowledge and piglet malnutrition of 46%, 27%, 19.4% and 15.6% respectively. Other instances where management knowledge has been seen to be crucial to maintain good ADG is genetics, parasite and disease prevention (Carter *et al.,* 2013). Furthermore, the management system that is the most common is the smallholder system by which pigs are housed in small pens, leftover food and crop by products are used as feeds for the animals; and the there is no set breeding program used in the herd (Amills *et al.,* 2012).

Literature conducted using a questionnaire in Tanzania found that 63% of gilts raised in a free-range system were mated at 5 to 8 months of age whereas 58% of gilts raised in a confined space were mated at 9 to 12 months of age (Lipendele *et al.,* 2015). At farrowing; the litter size in a free-range system was stated to be 5 to 8 piglets by 47% of the surveys conducted however; 58% of the surveys conducted where confined spaces were used found that average number of piglets born was 9 to 12 (Lipendele *et al.,* 2015). Moreover, majority of farmers using a free range system (43.3%) as well as farmers utilizing a confined space (51.7%) would wean 5 to 8 piglets (Lipendele *et al.,* 2015).

2.3.1 Challenges of the smallholder production

2.3.1.1 Infrastructure

'Soft' infrastructure incudes transportation, livestock management, marketing as well as money. 'Hard' infrastructure refers to roads, electricity, running water and irrigation as well as communications devices and facilities (Chaminuka *et al.,* 2008). The improvement of infrastructure can lead to the hastening of development, increase in personal drive, lessening the cost in order to get the product to market as well as increasing efficiency of production (Chaminuka *et al.,* 2008). Smallholder industry development and infrastructure development have a mutualistic relationship by which the development of the infrastructure available to the smallholders will lead to the improvement of the smallholder industry and in turn; the further developed smallholder industry then leads to additional infrastructure development (Chaminuka *et al.,* 2008). If more supplies and products are available to the smallholder farmers, the farmers will use the amenities more often which will lead to an increase in production (Kamara, 2004).

The four main infrastructural factors that limit smallholder farmers are the inadequate roads, the costly transport, the distance to markets (Mutua *et al.,* 2010) as well as the lack of access to service infrastructure (Chaminuka *et al.,* 2008, Mutua *et al.,* 2010). According to literature; the percentage of farmers accessing the amenities available weekly (58%) is close to the percentage of farmers that have access to roads of good quality (58%) which emphasizes that the quality of the roads available directly effects the utilization of the amenities and services available (Chaminuka *et al.,* 2008). A study conducted in the Free State found that 80.4% of the smallholder farmers that participated in the study did not use veterinary services to treat their pigs due to it being too costly, there not being a veterinarian available or the veterinarians could not access their farms due to the poor conditions (Nwafor *et al.,* 2019). Moreover, a study conducted in Western Kenya indicated that infrastructure lacking included roads to the market, a processing plant for the meat as well as a lack of a veterinarian that could treat pigs (Mutua *et al.,* 2010).

2.3.1.2 Nutrition

Literature suggests that there is nutrition, genetics and management strategies that could aid the smallholder farmers with their farming (Kanengoni *et al.,* 2015). Studies were conducted on the possible use of ensiled maize cobs in diets for resource poor farmers (Kanengoni et al, 2015). It was found that the local breed (Windsnyer) was able to adapt to the alternative feed (Hlatini *et al.,* 2020; Kanengoni *et al.,* 2015) and that the indigenous pigs required less protein thus allowing for the adaptation of the ensiled maize cobs (Kanengoni *et al.,* 2015; Hlatini *et al.,* 2020).

SA literature focusing on the nutritional practices of smallholder pig farmers found that the pigs were kept in pens but were able roam free to scavenge with the main source of feed being swill, maize and scraps (Amar *et al.,* 2021). Swill feeding is classified as feeding meat and meat byproducts to livestock; this feeding practice is of high risk due to the possible entrance and transmission of disease to the livestock (Schembri *et al.,* 2010; Matabane *et al.,* 2015) and is not accepted at the abbatoirs in SA (Matabane *et al.,* 2015). Despite this, it is still used in smallholder farming (Janse van Rensburg *et al.,* 2020). Studies conducted in SA have shown that 47% of smallholder farmers feed their pigs untreated swill (Janse van Rensburg *et al.,* 2020). Furthermore, a study conducted in the Western cape indicated that in Khayelitsha, Malmesbury and Mamre; 44%, 24% and 8% of the feed used was swill (Molotsi *et al.,* 2021). Moreover, literature shows that 53% of smallholder farmers' in Gauteng use swill as the main feed source due to the high cost of commercial feed (Matabane *et al.,* 2015).

Furthermore, a study conducted in Tanzania found that during the rainy season (December to May), fruit, fodder, and vegetables were the main source of feed and was supplemented with sunflower seed cakes or maize bran or both (Lipendele *et al.,* 2015). Maize bran was the most common source of feed during the time of maize harvesting (June to November), which was supplemented with fruits, vegetables and leftovers from the house (Lipendele *et al.,* 2015). Furthermore, if farmers bought food for mixing, the correct ratios were not not followed but rather added when needed due to availability (Lipendele *et al.,* 2015).

Household and kitchen waste were used as feed for the pigs in Sikkim, in the Eastern Himalayas (Nath *et al.,* 2013) which consisted of maize husks, mustard oil cake, the banana, sweet potato, tapioca and other indigenous plant stems, leaves and roots (Nath *et al.,* 2013). Only 5% of the farmers were able to buy commercial feed and the amount given to the pigs differed according to when it was available (Nath *et al.,* 2013).

2.3.1.3 Local pig genetic resources

The use of indigenous pigs is imperative for smallholder farmers as it is possible to have a high population number on a limiting piece of land, they are able to use food waste and crop residues for production (Halimani *et al.,* 2010) and can lead to improved food security and therefore improve the farmers' income (Halimani *et al.,* 2020).

There are 49 local African pig breeds and these breeds are resistant to local disease and pests (Penrith *et al.,* 2004). Of these 49 breeds 5% are endangered and 54% of these breeds status are unknown (Amills *et al.,* 2012, Halimani *et al.,* 2010). The origin of African swine breeds is not established which has led to the lack of knowledge about their relationship to their ancestors - *Sus Scrofa;* as well as their relationships between the different pig breeds (Amills *et al.,* 2012). It has been revealed that there is a significant contrast between the pigs found in West and East Africa (Amills et al., 2012). The swine in the western parts of Africa have alleles that are commonly found in t *et al.,* he European breeds while the eastern part of Africa contains alleles that are commonly found in East Asia (Ramirez *et al.,* 2009).

Local breeds in SA, Namibia and Mozambique contain a higher level of genetic diversity than the exotic breeds used such as the Landrace (Swart *et al.,* 2010). The Mukota; which is a local Zimbabwean breed is thought to be related to the Windsnyer-type and perhaps the Kolbroek, but the Windsnyer-type has not been investigated adequately and therefore there is no accurate description for the population size, risk status and characteristics (Halimani *et al.,* 2010). Images of these breeds can be found in Figure 2.2 below.

a. Mukota pigs.
http://www.livestockoftheworld.com/pigs/Breeds.asp?BreedLookupID=1856&SpeciesID=12&Screenwidth=479

b. Windsnyer pigs.
http://www.livestockoftheworld.com/pigs/Breeds.asp?BreedLookupID=1894&SpeciesID=12&Screenwidth=479

c. Kolbroek pig.
https://www.semanticscholar.org/paper/Phenotypic-and-reproductive-characterisation-of-Makhanya/953a7f8cbbbd262ce3ab1c7431e45a978c04fd22

Figure 2.2 Indigenous pigs found in South Africa and Zimbabwe

The most apparent constraint for conserving genetic diversity in smallholder farms is that the farmers do not participate in the conservation (Madzimure *et al.,* 2013). Smallholder farmers do not participate because the programmes available are too costly, unlawful or manipulative (Chimonyo & Dzama, 2007). Other threats to the conservation of indigenous pigs include their replacement with exotic breeds due to the economic benefit, poverty, lack of information, vague policies regarding conservation and uncontrolled crossbreeding with unclear objectives, bias in carcass grading systems and bias against local pigs (Halimani *et al.,* 2010).

In order to improve the participation of smallholder farmers in protecting the genetic diversity of their pigs are to develop the amenities that are available to the farmers. This is by developing infrastructure and organizations to aid them, to request the farmers to work together in order to lower cost of services available to them, activate policies by which there is an incentive for farmers to participate and to develop products suitable for the different smallholder farmers (Halimani *et al.,* 2020). Furthermore, farmers require information on the importance of genetic diversity of the indigenous pigs, pig husbandry training and recognition of their rights (Halimani *et al.,* 2010).

Breeding schemes need to consider the fact that the breeding goals of the smallholder farmers are different to those of the commercialised farms. The smallholder farmers look at additional traits such as, colour of the pig, behaviour, adaptability, and the capability of surviving under low management (Lekule & Kyvsgaard, 2003). According to literature, systems used to prevent inbreeding in smallholder systems are separation of the sows and boars (25%), borrowing a boar (16%), culling the boar early (9%) and trade boars that are unrelated (Madzimure *et al.,* 2013). Furthermore, 86% of the participants in the study preferred indigenous pigs due to the taste, juiciness, tenderness and colour of the meat (Madzimure *et al.,* 2013). The participants required for conservation include national government to create legislation, farmers of all size, researchers, breeding companies and the consumer (Halimani *et al.,* 2010).

2.1.3.4 Biosecurity and disease prevention

According to literature, helminths are also a main challenge for the smallholder farmers (Sithole *et al.,* 2020, Krecek *et al.,* 2012, Sithole *et al.,* 2019; Franssen *et al.,* 2019). One of the most common parasitic zoonotic diseases that occur in SA is *Taenia solium* which can cause epilepsy and other neurological diseases (Sithole *et al.,* 2020). In order to prevent porcine cysticercosis and taeniasis; the prevention of pigs eating infested faeces and thus prevention of humans eating infected meat is required (Sithole *et al.,* 2020). *T. solium* cysticercosis in both man and swine is ignored and underreported (Praet *et al.,* 2010) despite it being one of the most significant food borne diseases (FAO, 2014) and that it can lead to severe production losses and in turn, food for the smallholder farmers. There has only been one report by which it was found that 64.6% of the farms in villages in the Eastern Cape have been infected by *T.solium* (Krecek *et al.,* 2012). Furthermore, literature conducted in Tanzania in Mbozi and Mbeya rural districts, found that mange and porcine cysticercosis to be the most frequent disease in the study area (Lipendele *et al.,* 2015). Out of the 141 pigs tested, 26% of them tested positive for porcine cysticercosis; Ihanda and Mshewe had the highest prevalence with 52% 33% and respectively (Lipendele *et al.,* 2015). Moreover, 61% of the pigs sampled tested positive for four species of gastrointestinal worms (Lipendele *et al.,* 2015).

Studies have reported that an inspection of the meat only is not sufficient in order to identify the *T.solium*; but rather the heart, shank, tongue and masticatory muscle should be inspected (Sithole *et al.,* 2019). A local study found that only 54% of smallholder consumers understood that consuming meat contaminated with cysticercosis is detrimental to their health and 42.7% stated that they knew how to identify cysticercosis cysts when pigs are slaughtered at their home (Sithole *et al.,* 2020). However; many indicated that they could not differentiate between fat and a cysticercosis cyst, did not know the symptoms of both porcine cysticercosis or human cysticercosis and 45.9% believed that pork with cysticercosis is not harmful (Sithole *et al.,* 2020). The individuals in the study (<40%) indicated that they trust the pork purchased from their local butchery, only 11.3% stored their pork in the freezer and 67.7% of the consumers preferred cooking the pork in a stew – which is the traditional way (Sithole *et al.,* 2020). The percentage of individuals who freeze their pork and cook their pork in a stew is important knowledge as it is known that freezing meat that is contaminated *T.solium* between -5 and -24˚C for 1 to 4 days can inactivate the *T.solium* eggs (Franssen *et al.,* 2019). Furthermore, the stewing of pork meat contaminated with *T.solium* eggs for a long period of time ensures that the pork reaches an internal temperature of 65˚C which also inactivates the *T.solium* eggs (Franssen *et al.,* 2019). The only way to prevent and control this parasite is by vaccinating the pigs and treating the infected humans and pigs (Ngwili *et al.,* 2021).

ASF is an extremely contagious virus that is found in both wild and domestic pigs whose symptoms are a fever, haemorrhages of the skin and organs, anorexia, dark urine and bloody diarrhoea (Sur, 2019; Amar *et al.,* 2021). Post mortem identifiers include congestion and reddening of the skin of the neck and ears (Amar *et al.,* 2021). ASF is not a zoonotic disease however it is very contagious and it is spread mainly through humans when there are no biosecurity measures in place (Janse van Rensburg *et al.,* 2020; Penrith et al *et al.,* 2019). Pigs come into contact with the virus by eating untreated swill, coming into contact with an infected pig's faeces or machinery and equipment that has been contaminated with ASF (Janse van Rensburg *et al.,* 2020; Teklue *et al.,* 2020). Furthermore, in smallholder farming, factors that can lead to ASF epidemics are using auctions, the system in which the pigs are marketed and not having access to abattoirs which have accurate meat inspection processes (Penrith *et al.,* 2013).

Despite efforts to find a vaccine for ASF it has been unsuccessful (Teklue *et al.,* 2020). This is due to the fact that the DNA of the ASF Virus (ASFV) is complex and substantially sized. Also, there are 24 ASF strains which mutate and develop over time (Sur, 2019; Teklue *et al.,* 2020). Even though there is no vaccine for ASF; a study in Malawi in 1985 discovered that the use of serological surveys can indicate if a location has become endemic for ASF (Haresnape *et al.,* 1987). In order to prevent outbreaks biosecurity measures are required however due to an absence of information about ASF the smallholder farmers do not know which measure to implement (Janse van Rensburg *et al.,* 2020). Therefore, programmes to educate the smallholder farmers, extension officers and leaders in the community need to be implemented (Penrith *et al.,* 2007). Biosecurity programmes not only avert ASF outbreaks but also prevent transmission of other diseases (Janse van Rensburg *et al.,* 2020; Amar *et al.,* 2021).

The first ASF epidemic was in 2012 (Amar *et al.,* 2021) when the ASF breakout occurred outside the control zone; due to the illegal transportation of pigs from the control zone to an auction (Janse van Rensburg *et al.,* 2020). This epidemic was declared over when in 2013 a national survey was conducted in order to test for ASF antibodies and all came back negative (Janse van Rensburg *et al.,* 2020). The second epidemic was in the years 2016 and 2017 by which there was localized outbreaks in the North West, Northern Cape and Free State (Janse van Rensburg *et al.,* 2020; Amar *et al.,* 2021). In order to end the epidemic a controlled culling programme was followed by which all pigs in enclosed estates were culled and in areas where they were not contained – the smallholder farms – were culled if they were showing the symptoms of ASF (Janse van Rensburg *et al.,* 2020). The third and most recent local outbreak was in 2019 continuing into early 2020 in the provinces Gauteng, Mpumalanga, Eastern Cape and the Free State (Amar *et al.,* 2021).

A SA study was conducted on smallholders' knowledge and management practices regarding ASF. The results indicated that 20% of the farmers knew that their pigs were not contained and could have in contact with a wild boar and only 14% bought their pigs from an auction (Janse van Rensburg *et al.,* 2020). Furthermore, 78% of the smallholder farmers did not have any biosecurity programmes in place with majority of these farmers (73%) stating that it is due to lack of knowledge however this is also due to them being costly (Penrith *et al.,* 2019). The implementation of biosecurity measures is crucial because the epidemic in 2016 and 2017 only affected smallholder farmers (Janse van Rensburg *et al.,* 2020).

In addition, another study found that there were no biosecurity programmes in place (Amar *et al.,* 2021). The farmers wore normal clothes with no designated footwear for the pens and there was no disinfectant (Amar *et al.,* 2021). It was found that the smallholders' pigs in Ratanda had ASF; the pigs were quarantined, subsequently culled, disposed using a deep burial and the pig pens were covered in hydrated lime to disinfect the area (Amar *et al.,* 2021).

Moreover, smallholder farmers in the Eastern Himalayas experienced worms, mange, diarrhoea, anaemia and pneumonia as the most common (Nath *et al.,* 2013). There was a significant different between the piglet mortalities at one month and the mortalities between 1 to 3 months of age; however, there was not significant difference between piglet mortalities between 3 to 6 months of age and older than six months of age (Nath *et al.,* 2013). Despite gastrointestinal worms being a main disease experienced in western Kenya; smallholder farmers did not know how to identify when their animals were ill and required treatment for such ailments (Mutua *et al.,* 2010).

The aspects studied with regards to smallholder farming (Table 2.5) indicate the possible areas of improvement required for the smallholder farmers to enter the commercial industry.

Table 2.5 A summary of the main constraints reported in smallholder production

Aspects studied	Country	Reference
Infrastructure	South Africa Kenya	Chaminuka *et al.,* 2008 Mutua *et al.,* 2010
Nutrition	South Africa South Africa South Africa Tanzania South Africa South Africa South Africa India	Hlatini *et al.,* 2020 Janse van Rensburg *et al.,* 2020 Kanengoni *et al.,* 2014 Lipendele *et al.,* 2015 Matabane *et al.,* 2015 Molotsi *et al.,* 2021 Munzhelele, 2017 Nath *et al.,* 2013
Breeding	Zimbabwe South Africa; Zimbabwe South Africa Kenya South Africa Zimbabwe	Chimonyo & Dzama, 2007 Halimani *et al.,* 2010; 2012; 2020 Madzimure *et al.,* 2013 Mutua *et al.,* 2010 Swart *et al.,* 2010 Zanga *et al.,* 2003
Biosecurity and disease	South Africa South Africa South Africa South Africa Tanzania South Africa Kenya India South Africa South Africa	Amar *et al.,* 2021 Harensnape *et al.,* 1985 Janse van Rensburg *et al.,* 2020 Krecek *et al.,* 2012 Lipendele *et al.,* 2015 Sithole *et al.,* 2019, 2020 Mutua *et al.,* 2010 Nath *et al.,* 2013 Nwafor *et al.,* 2019 Penrith *et al.,* 2013; 2019

Thus it is clear that smallholder farmers face a number of challenges that are similar to those of a commercial farmer however certain challenges affect only the smallholder farmer.

2.4 Conclusion

Whereas the commercial houses have specialised ventilation, lighting, buildings and manure removal the smallholder farmers have basic outdoor projections which usually consist of wood, sheet metal and earth floors. Commercial farmers use specialized feed to maintain a BCS and biosecurity to prevent the spread of disease; whereas smallholders use leftovers from the house, swill and infrequently bought commercial feed and do not practice biosecurity. Majority of the research in the pig industry focuses on the commercial farms in all aspects and contrastingly, aspects of smallholder pig farming still need to be further researched in order to understand the unique requirement of the various smallholder farmers to help them enter the commercial industry.

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Chapter 3

An analysis of production traits in South African small- medium and large commercial pig production units

3.1 Introduction

The South African (SA) pork industry is dynamic and has both a commercial and informal sector (Venter, 2019). The commercial and informal producers have increased over the past decade but for different reasons. Commercial pork production has increased by 42% over the last decade in order to be able to provide for a growing consumer demand which has grown by 48% over the same period (BFAP, 2020). The informal sector is less studied but it was found that in 2016 there were approximately 211 000 households participating in informal pig farming compared to the 113 000 reported in 2011 (BFAP, 2020). This increase in number is due to this sector providing mainly food for the household but also as a supplier of income (Gcumisa, 2013). Commerial pork producton in SA uses a completely intensive system which requires large capital inputs (BFAP, 2021) which contrasts other livestock production systems such as beef (du Plessis *et al.,* 2006). Due to the large amounts of capital required small, medium and large farms differ significantly in both the physical structure but also management practices (Visser, 2014); and due to the requirement of capital - the informal sector continues to grow.

In SA there are three companies responsible for genetic improvement, Topigs Norsvin SA Pty Ltd, Danbred Africa (Pty) Ltd and PIC South Africa, which utilize modern genetics in combination with intensive feeding, housing and biosecurity methods (BFAP, 2021). Vertical integration is evident as the breeding schemes, artificial insemination and contract growers are all owned by a select few companies (USDA, 2017; DAFF, 2019). The SA commercial pig farms currently vary and range from small to large in size with less than 200 sows to over 1000 sows (Visser, 2014). In contrast, the informal sector consisting of smallholder farmers and pig keepers contains a herd population of 900 000 pigs on which there is no information (BFAP, 2020). SA has no classification of small, medium and large pig farms but do distinguish between commercial and developing pig keepers (BFAP, 2020)

The international trend in the United States of Amercia (USA) and Canada is towards larger pig production operations. Data collected in USA shows variation in commercial farms from 110 sows to more than 10 000 sows with 44% having less than 1 000 sows, 20.3% have between 2 000 and 2 999 sows, 5.5% had between 3 000 and 3 999 and 7% had more than 4 000 sows (National Hog Farmer, 2022). In the USA, farm size will influence the operation of the farm: larger farms would have only breeding to weaning production stages whereas small and medium farms would operate farrow to finish (Knox *et al.,* 2014). In Canada the average number of sows on the farm increased from 2006 to 2011 by 32% (Robbins *et al.,* 2016).

In contrast to the USA literature, in European countries such as Poland, the majority of farms in 2011, had less than 20 sows (Dors *et al.,* 2013), indicating small units. A similar trend was reported for Poland and Romania by Bellini (2021), with only 33% of farms having a sow size of 400. Sweden has around 1300 registered pig farms and 79% produce fatteners while 61% keep sows for breeding (Pettersson *et al.,* 2021). With regards to farm size 58% of the registered farms keep less than 100 sows (small), 32% keep 100-500 sows (medium) and 10% house more than 500 sows (large) (Pettersson *et al.,* 2021). Literature also shows that the average number of breeding sows per farm has increased in Estonia, the Czech Republic, Latvia, Slovenia and Hungary and by 14% since 2007 but sow number decreased in Bulgaria, Ireland, Cyprus, Slovakia and Unite Kingdom (Bellini, 2021).

Developing countries show varying results with regards to sow herd size. The pig farms in China have more than 1000 sows which have increased by 55% between 2007 and 2009 (Robbins *et al.,* 2016). In Thailand, smallholder, small, medium and large farms are classified as less than 50 sows, 50-500, 500-5000 and more than 5000 sows respectively (Thanapongtharm *et al.,* 2016). Smallholder farms hold the highest number of farms with 95%, followed by small (3.86%), medium (1%) and large (0.11%) commercial farms (Thanapongtharm *et al.,* 2016). These farm values include farrow to finish and/or nurseries and/or finishing systems (Thanapongtharm *et al.,* 2016). Corresponding with Thailand, the herd size in three of Cameroon's subdivisions Dschang, Fokoué and Penka Michel had average sow numbers of 17.14±11.62, 21±9.89 and 15.21±10.67 (Kouam *et al.,* 2020). While the expectation is that pig farms in Asia will continue to increase, farm size in Africa is expected to decrease (Masters *et al.,* 2013; Jayne *et al.,* 2003). There is a dearth of information available on the effect of farm size in Africa, average farm size and the number of sows or specific system utilized (Jayne *et al.,* 2016; Jayne *et al.,* 2019).

Due to the intensive nature of pig production traits such as average number born alive (NBA), average number of stillborn piglets (NSBP), average number of mummified piglets (NMP), average number of piglets weaned (NPW), average weaning weight (WWP), average number of pigs slaughtered (NPS), average weight of pigs slaughtered (SLAUW) and percent of prewean mortality (MORT) are important. Feeding, genetic improvement disease prevention and management are dependent on farm size (Dewey *et al.,* 1997; Pettersson *et al.,* 2021; Hemme *et al.,* 2018). Limited literature indicates that large farms are more likely to use feed additives however; of the farms utilizing feed additives, small farms are 7.7 times more likely to utilize only feed additives approved for pig production (Dewey *et al.,* 1997). Studies show that medium and large farms clean and disinfect the houses between batches more frequently (Pettersson *et al.,* 2021) and have a higher level of antibiotic use (Hemme *et al.,* 2018). In addition, small farms will more frequently not place water and feed over the slats in the floor which can lead to a wet damp area for pathogens to grow (Pettersson *et al.,* 2021). Farm size and number of sows will influence level of management required.

Despite the presence of larger percentages of small pig farms in developing countries it has been indicated that larger pig farms have a higher level of sow mortality (Koketsu, 2000b; Christensen *et al.,* 1995; Abiven *et al.,* 1998). This could be due to the hired labour not focusing on recognition of sub-clinical signs of disease in time (Koketsu, 2000b). Studies conducted in both North and South Vietnam (Jabbar & Akter, 2008) and Hawaii (Sharma *et al.,* 1999) found that large (>75 sows) pig farms were the most efficient (Jabbar & Akter, 2008; Sharma *et al.,* 1999) and made the most profit (Sharma *et al.,* 1997b). It was also found that in China; technical efficiency is higher in large-scale pig farms and medium-scale farms have the lowest level of manure processing, making this farm size the least environmentally efficient (Yan *et al.,* 2020). However, this could be due to medium-scale farms having less government funding compared to large pig farms (Yan *et al.,* 2020).

Due to the growing developing sector it is of interest to benchmark production in terms of the most important traits in a small, medium and large commercial pig unit. The aim of this chapter was to analyse available production data for small medium and large production units in SA with similar infrastructure and using Pigvison for performance recording to obtain a benchmark of fertility and post weaning traits.

3.2 Materials and Methods

This study analysed data provided by Danbred for six commercial units with the required consent. Ethical approval was granted by the ethics committee of the faculty of Natural and Agricultural Sciences (NAS262/2021) for the analyses of external data.

The raw data from six anonymous farmers was provided by Danbred from the program PigVision. These farms represented small, medium and large farms and are presented in Table 3.1. One of the management tools utilized by commercial farmers is Pigvision; a comprehensive, user-friendly computer program which allows for each farmer to personalize the functions, recording of traits and the showing of trends within the data (AgroVision, 2021).

Table 3.1 The six farms representing small, medium and large farms

Farm number	Number of Sows	Allocated farm size
1	250	Small
2	1 800	Large
3	3 000	Large
4	1 000	Medium
5	1 200	Medium
6	650	Small

The records were filtered for particular traits required such as NBA, NSBP, NMP, MORT percent, NPW, WWP, NPS and SLAUW and captured into excel tables. Data records between the years of 2017 and 2021 were extracted and captured in excel tables per trait, after which only complete records were extracted from these tables. Tables per trait were compiled for statistical analysis. In Table 3.2 the completeness of the data for the farms are shown. The farms were then grouped into small, medium and large farms where each group had two farms.

Table 3.2 The completeness of the data records taken from Pigvision from 2017 to 2021

Farm size	Average NBA	Average NSBP	Average NMP	MORT (%)	Reasons for MORT	Average number NPW	Average WEANW	Number NPS	Average SLAU weight (kg)	Average Live weight (kg)
Small	90%	100%	100%	100%	100%	40%	40%	40%	40%	20%
Medium	90%	100%	100%	100%	100%	90%	60%	50%	30%	0%
Large	95%	100%	100%	100%	100%	100%	55%	60%	60%	0%

Analysis of this grouped data was performed using R software (version 4.1.3. available at http://www.Rproject.org) using the Mann-Whitney U test and Fisher's Exact test (Rice, 2006) to test for significant differences between small, medium and large farms. These non-parametric statistical tests were used due to violations in underlying assumptions of their parametric counterparts.

The Mann-Whitney U test was utilized for the analyses of the average NBA, NSBP, NMP, NBA per parities for parities one through nine. This particular test was used due to the records already being summarized when taken from Pigvision. This test was used to determine whether two samples come from the same population. Although it is a non-parametric test it does assume that the two groups being compared are independent and that the shape of the two groups must be similar. The average values and percent from Pigvision were used in the calculations in order to account for bias due to the farm's size. The tests for significance took place at 10% significance level in order to be less stringent and thus if our resultant p-value is less than 0.1, we would reject the null hypothesis and conclude that the distribution between the two groups (i.e. the type of farm) are not equal, and hence there is a significant difference between them. The generalized hypothesis test would be as follow (Bain & Engelhardt, 1992):

H_0: The distribution of the two groups (i.e. the two different types of farms being compared) are equal.

H_a: The distribution of the two groups are not equal.

It is calculated in the following manner:

$U_1 = n_1n_2 + \frac{n(n1+1)}{2}$ and

$U_2 = n_1n_2 + \frac{n(n2+1)}{2}$

The use of Fisher's Test over the Chi-Squared test is due to the underlying assumption of the Chi-Squared test requiring a minimum count of 5 in each cell of a frequency table, which we do not have in this case. If the resultant p-value of this test is less than 10%, we would reject the null hypothesis and conclude that we have a relationship between the two variables. In addition to the Fisher's exact test, odds ratios were calculated where applicable to obtain further statistical and numerical insights into the relationships between these variables of interest. The hypothesis for Fisher's Exact test is as follows:

H0: The variables are independent and there is no relationship between the two variables.

Ha: The variables are dependent and there is a relationship between the two variables

Following this; tables, pie charts, bar graphs and box plots were created using R studio (version 4.1.3. available at http://www.Rproject.org) to visually see the phenotypic trends of the small, medium and large farms.

3.3 Results

Results for the NBA, NSBP, NMP, NPW, WWP, NPS, SLAUW AND MORT are summarized in Table 3.3. NBA varied slightly from 12.95 on small farms to 13.2 on large farms. Still born piglets were highest in small farms whereas mummified piglets were highest in large farms. Overall % MORT and % of MORT due to be being laid on were highest in large farms.

Table 3.3 Descriptive statistics for NBA, NSBP, NMP, % MORT and % MORT due to being laid on

Farms	Min	Max	Median (IQR)	Mean (SD)
NBA				
small farms	0.74	12.95	1.15 (12.95)	12.95 (0.74)
medium farms	0.15	12.39	0.15 (12.39)	12.39 (0.32)
large farms	0.4	13.2	0.6 (13.11)	13.11 (0.4)
NSBP				
small farms	0.04	1.15	0.05 (1.14)	1.14 (0.04)
medium farms	0.05	0.54	0.05 (0.54)	0.54 (0.1)
large farms	0	0.9	0 (0.88)	0.88 (0.04)
NMP				
small farms	0.13	0.36	0.2 (0.36)	0.36 (0.13)
medium farms	0.05	0.15	0.05 (0.13)	0.13 (0.06)
large farms	0.04	0.63	0.05 (0.63)	0.63 (0.04)
% MORT				
small farms	8.911988912	12.43822674	11.23 (0.869)	11.09 (0.67)
medium farms	7.669105928	8.337486761	8.14 (0.24)	8.1 (0.3)
large farms	9.152450826	11.56721902	10.32 (0.679)	10.53 (0.99)
% MORT due to being Laid on				
small farms	37.62781186	54.94548287	40.77 (13.6)	45.29 (8.19)
medium farms	32.06703911	44.85335326	33.4 (4.89)	36.25 (5.31)
large farms	36.37044667	45.7657126	39.55 (1.86)	40.04 (3.52)

Furthermore, the median of both NBA and NPW per parity can be found below in Figures 3.1 and 3.2 respectively. The descriptive statistic tables can be found in Addenda A and B.

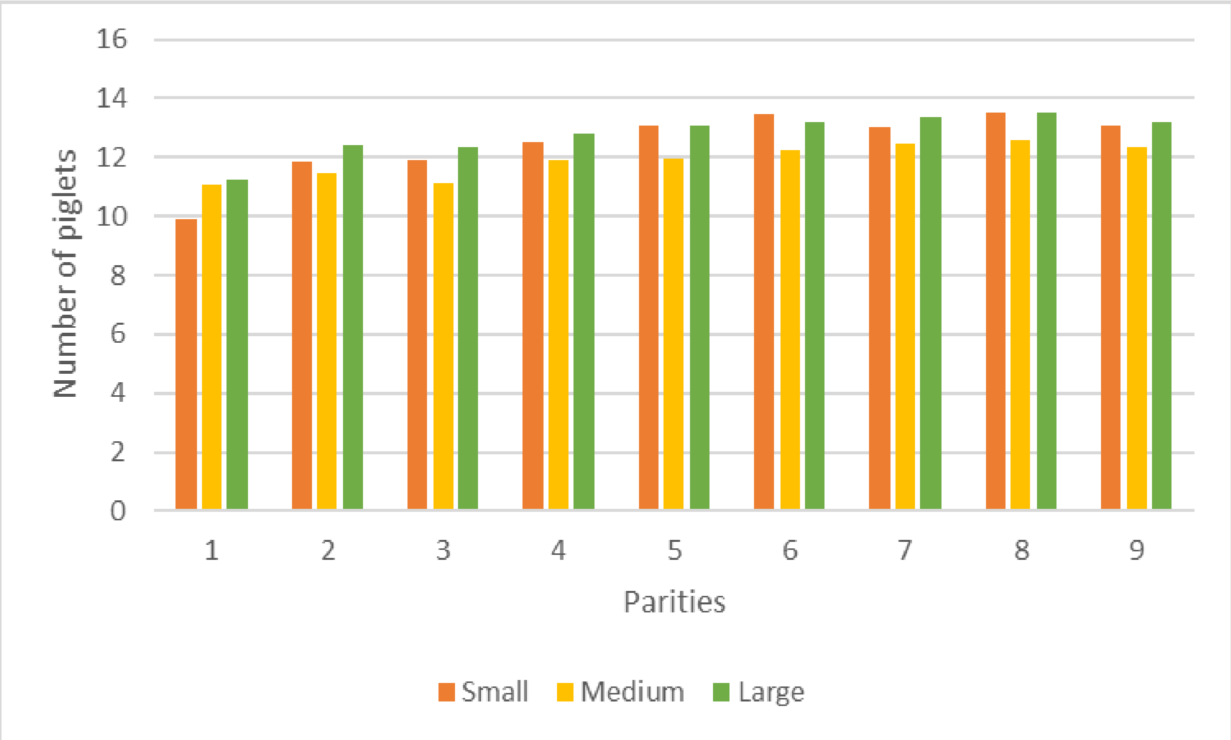

Figure 3.1 Median values for number born alive per parity

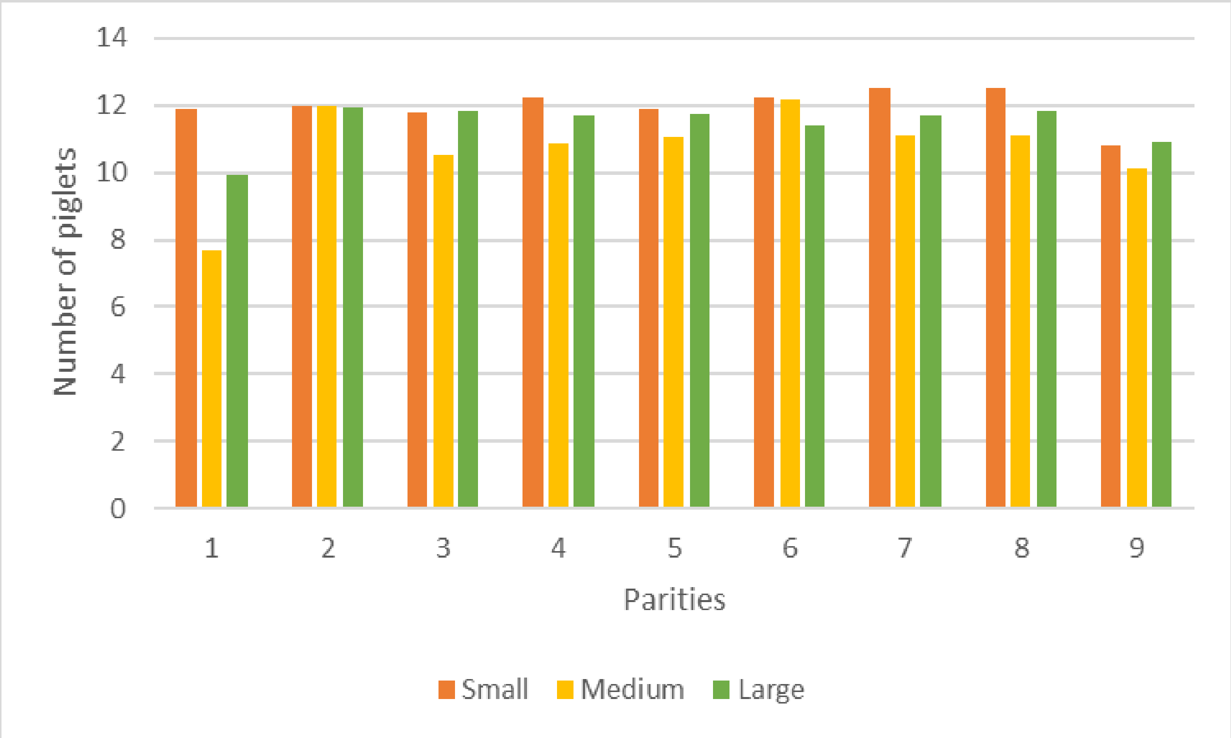

Figure 3.2 Median values for number of piglets weaned per parity

The variation for average NBA, NSBP and NMP for small, medium and large farms is displayed in Figures 3.3, 3.4 and 3.5.

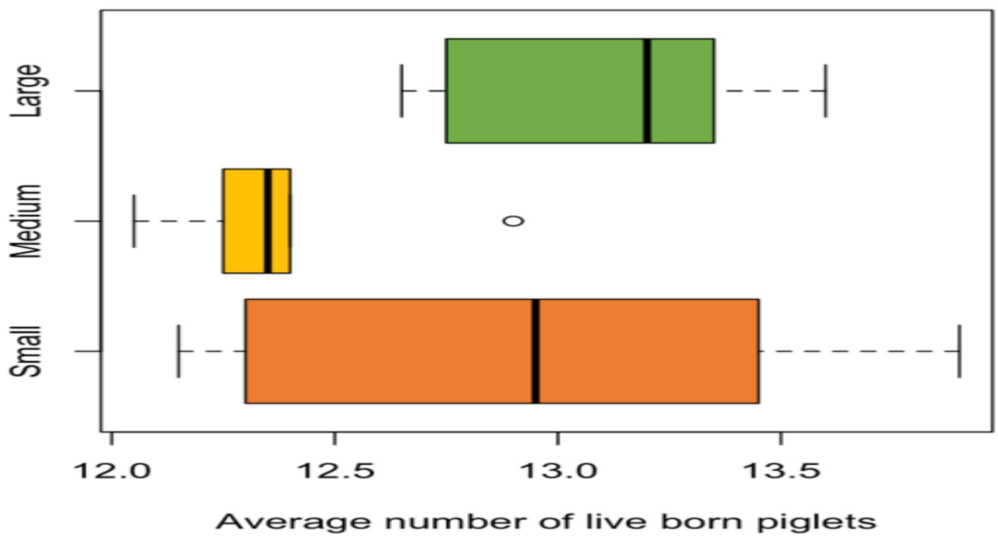

Figure 3.3 The average number born alive for small, medium and large farms

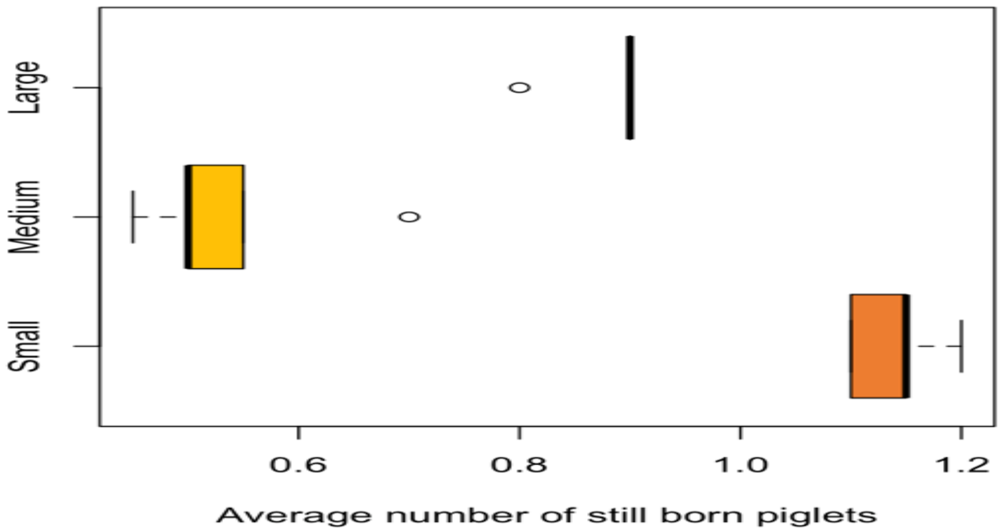

Figure 3.4 The average number of stillborn for small, medium and large farms from 2017 to 2021

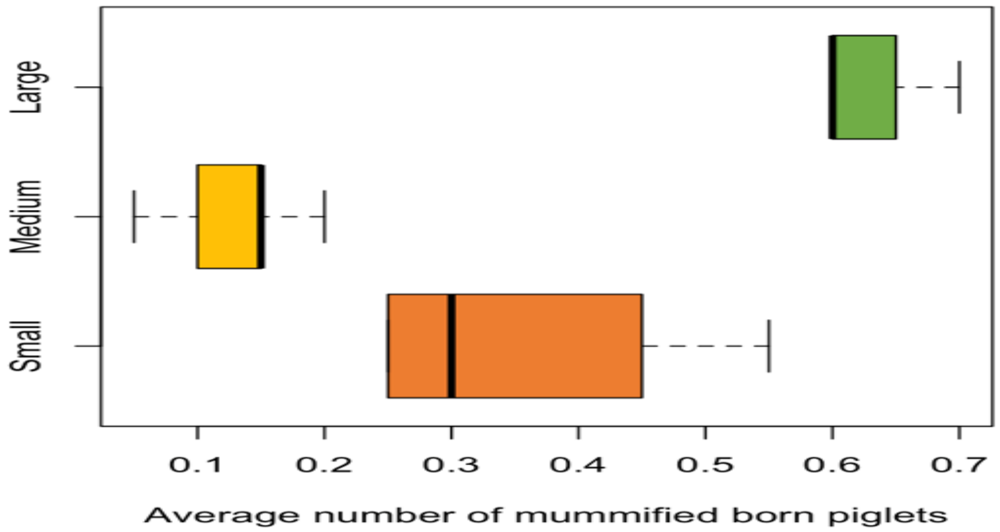

Figure 3.5 The average number of mummified born for small, medium and large farms from 2017 to 2021

The Mann-Whitney U test utilized indicated a significant difference only between medium and large farms for the average NBA. However, for both the average NSBP and NMP; there were significant differences between small and medium farms, medium and large farms as well as small and large farms which is indicated in Table 3.4.

Table 3.4 The Mann-Whitney U test results testing for significant difference of NBA, NSBP and NMP between small, medium and large farms

Variable	Farm Size Comparisons	Test Statistic	P-Value
Live Born Piglets	Small vs. Medium	7	0.310
	Small vs. Large	14	0.841
	Medium vs. Large	23	0.032*
Still Born Piglets	Small vs. Medium	0	0.011*
	Small vs. Large	0	0.009*
	Medium vs. Large	25	0.009*
Mummified Piglets	Small vs. Medium	0	0.012*
	Small vs. Large	25	0.012*
	Medium vs. Large	25	0.012*

*p-value<0.1

In addition, the variation for NBA for parities one to nine for small, medium and large were investigated and parities exhibiting significant differences are displayed in Figure 3.6. Parity 9 did not display significant difference and its relevant boxplot can be found in the addendum. Due to incomplete records for parities higher than nine they were not analysed.

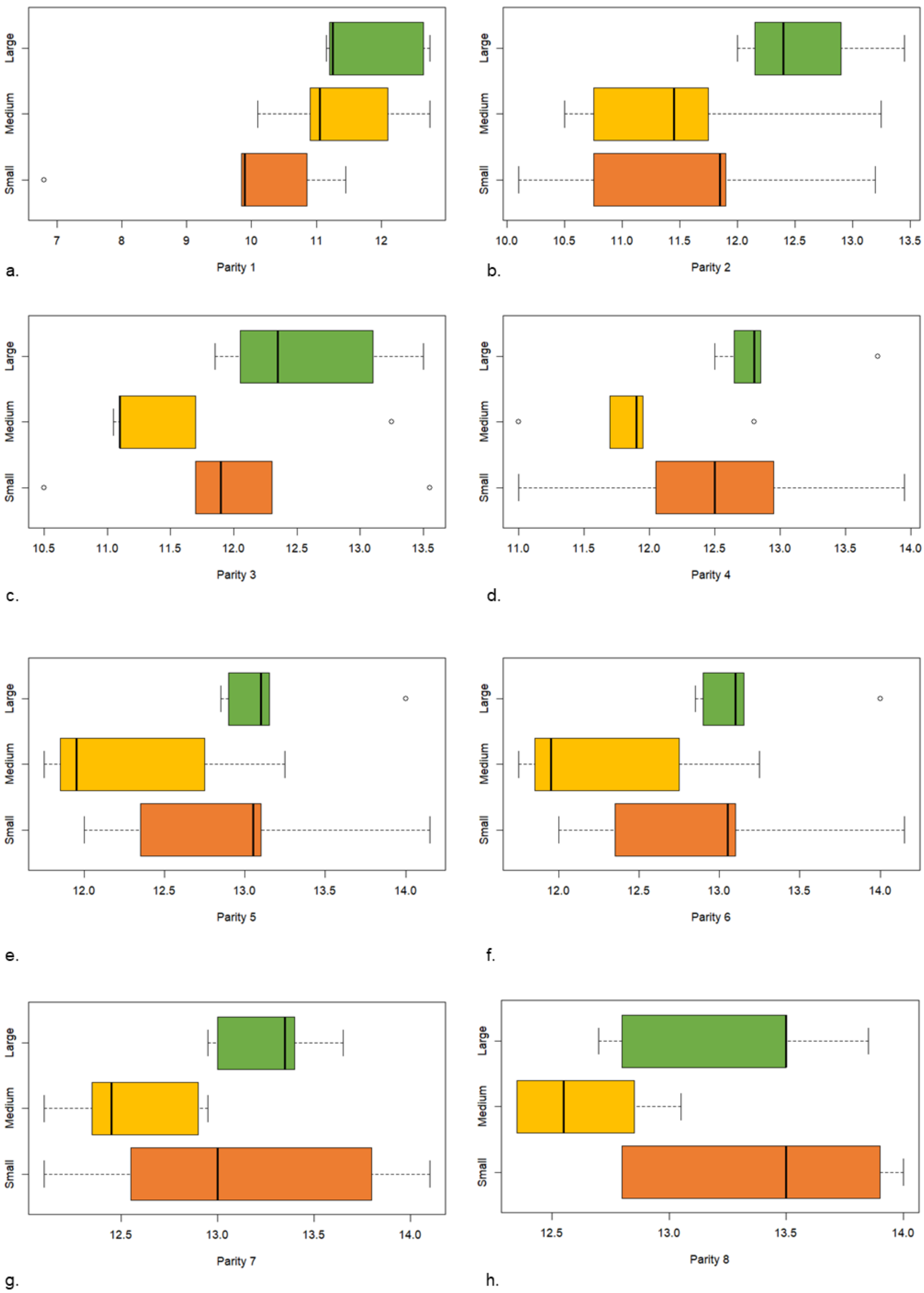

Figure 3.6 The spread of data for the number born alive for parities one to nine.

The summarized results for the test for significant difference between small, medium and large farms can be found in Table 3.5.

Table 3.5 The Mann-Whitney U test results testing for significant difference of average NBA for parities one to nine between small, medium and large farms

Parity	Farm Size Comparisons	Test Statistic	P-Value
1	Small vs. Medium	21.0	0.095*
	Small vs. Large	22.0	0.056*
	Medium vs. Large	17.5	0.346
2	Small vs. Medium	11.5	0.917
	Small vs. Large	21.0	0.095*
	Medium vs. Large	21.0	0.095*
3	Small vs. Medium	8.5	0.463
	Small vs. Large	17.0	0.421
	Medium vs. Large	21.0	0.095*
4	Small vs. Medium	6.5	0.249
	Small vs. Large	15.5	0.600
	Medium vs. Large	22.5	0.047*
5	Small vs. Medium	6.0	0.222
	Small vs. Large	15.5	0.600
	Medium vs. Large	21.0	0.095*
6	Small vs. Medium	4.5	0.115
	Small vs. Large	11.0	0.841
	Medium vs. Large	23.0	0.036*
7	Small vs. Medium	6.0	0.222
	Small vs. Large	13.5	0.917
	Medium vs. Large	24.5	0.016*
8	Small vs. Medium	4.0	0.093*
	Small vs. Large	9.0	0.521
	Medium vs. Large	21.0	0.093*
9	Small vs. Medium	6.0	0.222
	Small vs. Large	13.0	1.000
	Medium vs. Large	19.5	0.173

*p-value<0.1

The results with regards to MORT from 2017 to 2021 in small, medium and large farms are displayed in Figure 3.7. Furthermore, signifcant difference was found when analysing the total MORT on small, medium and large farms which can be seen in Table 3.6.

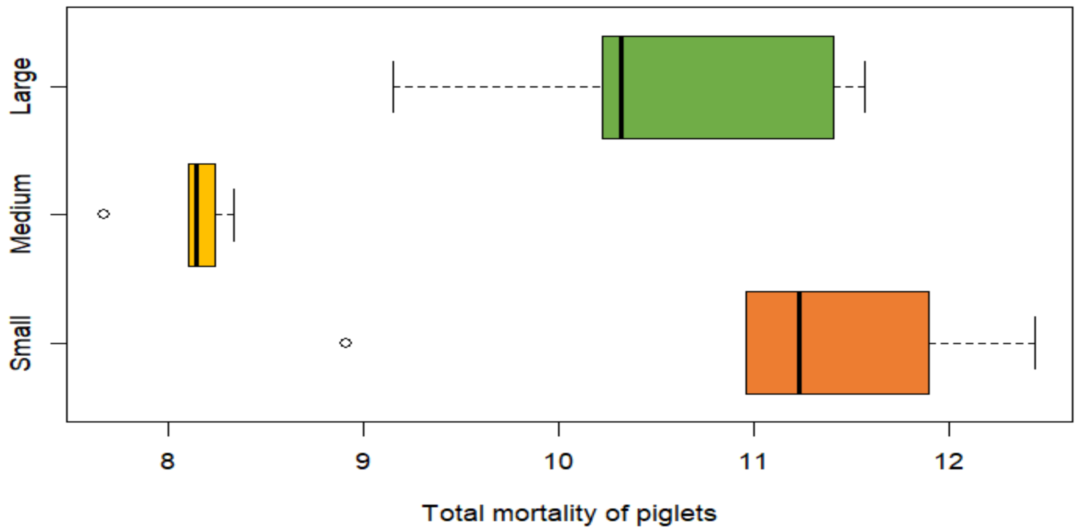

Figure 3.7 The percent mortality on small, medium and large farms.

Table 3.6 The Mann-Whitney U test results testing for significant difference of total MORT between small, medium and large farms

Farm Size Comparisons	Test Statistic	P-Value
Small vs. Medium	0	0.008*
Small vs. Large	9	0.548
Medium vs. Large	25	0.008*

*p-value<0.1

The three main causes for MORT on small farms is being laid on, low viability and being weak with percentages of 40.01, 50.32 and 6.79% respectively (Figure 3.8). Medium farms experience being laid on (45.05%), being a runt (25.95%) and being too thin (9.23%) as the main causes of MORT (Figure 3.9). In addition, large farms' four main causes for MORT are being laid on, being sick and having joint ill and scours/diarrhoea with 49.27 and 7.29, 7.28 and 7.9% respectively (Figure 3.10).

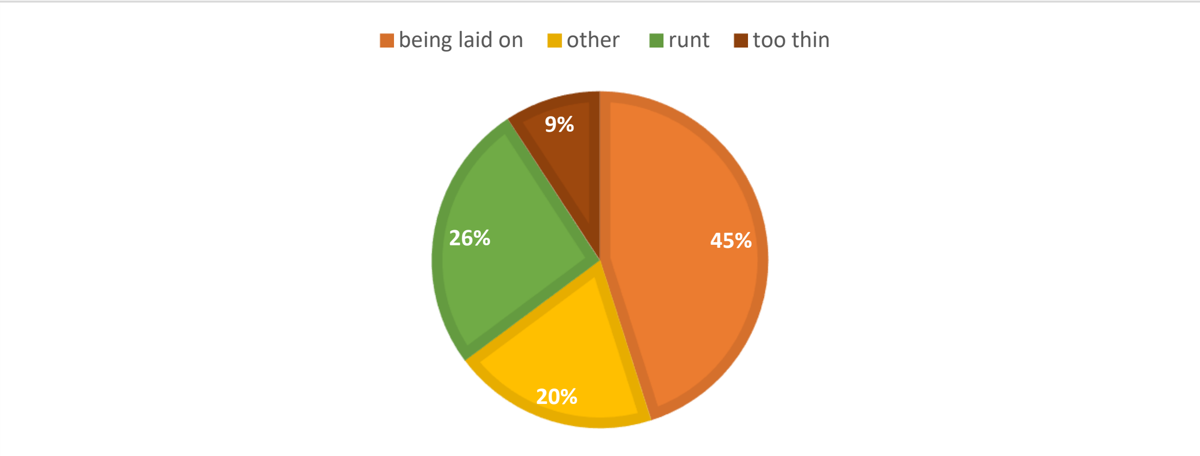

Figure 3.8 The three main causes of MORT on small farms in 2021.

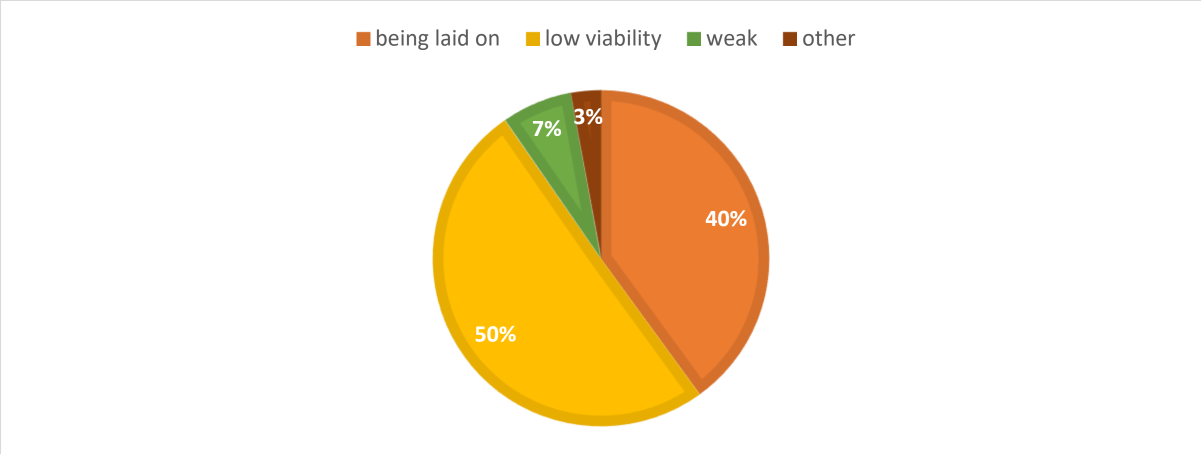

Figure 3.9 The three main causes of MORT on medium farms in 2021.

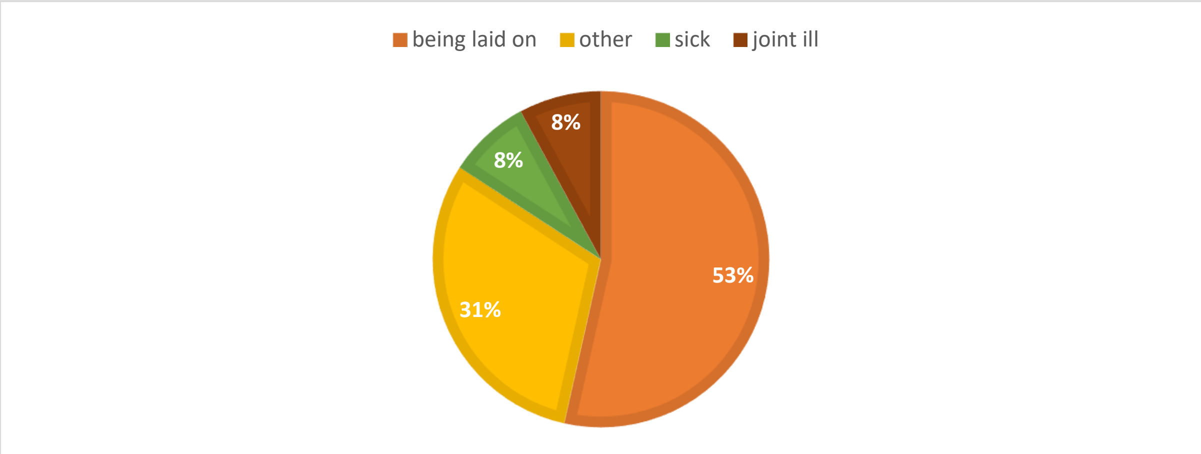

Figure 3.10 The four main causes of MORT on large farms in 2021.

Furthermore, the percent of MORT due to being laid on for small, medium and large farms from 2017 to 2021 is displayed in Figure 3.10. Small farms levels decreased from 53.34 to 39.74% whereas medium and large farms levels increased from 33.01 to 44.85% and 40.18 to 45.77% respectively. Furthermore, testing for a significant difference between small, medium and large farms with regards to percent of MORT due to being laid on was conducted. Results indicated there is only a significant difference between small and medium farms (Table 3.7)

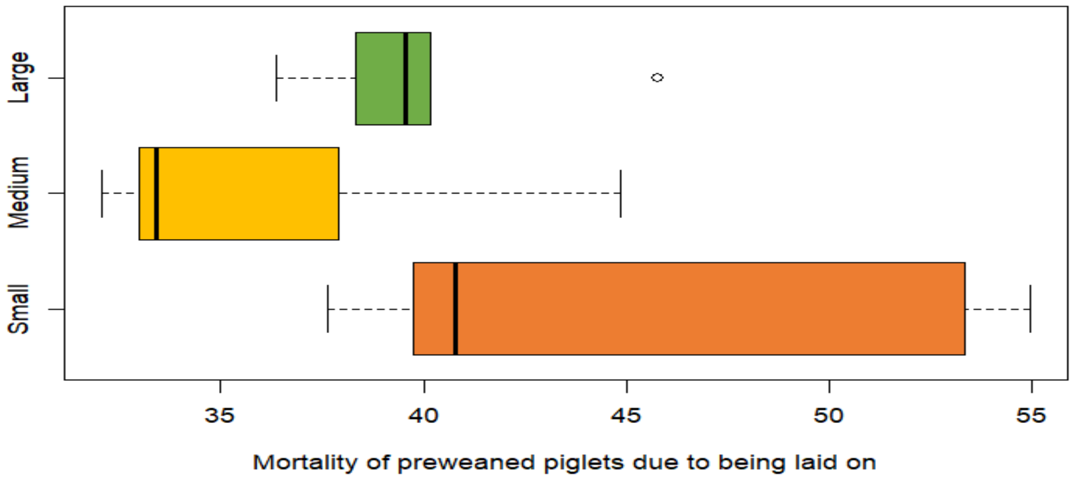

Figure 3.11 The percent of mortality due to being laid on for small, medium and large farms**.**

Table 3.7 The Mann-Whitney U test results testing for significant difference of percent MORT due to being laid on between small, medium and large farms

Farm Size Comparisons	Test Statistic	P-Value
Small vs Medium	21	0.095*
Small vs Large	18	0.310
Medium vs Large	5	0.151

*p-value<0.1

In addition to testing for a significant difference with regards to percent MORT and percent being laid on for small, medium and large farms; it was determined that there is a relationship between the cause of mortality and farm size (Table 3.8).

Table 3.8 The Fisher's exact test results to determine if there is a relationship between cause of MORT and farm size.

		Size of Farm	
Cause of Death	**Small**	**Medium**	**Large**
Laid on	1374	2401	5008
Other	2060	2928	5157
Total	3434	5329	10165

The variation of NPW for parities that had significant differences between small, medium and large farms are displayed in Figure 3.12. The parities that did not show a significant difference can be found in the addendum. Due to incomplete records for parities higher than nine they were not analysed.

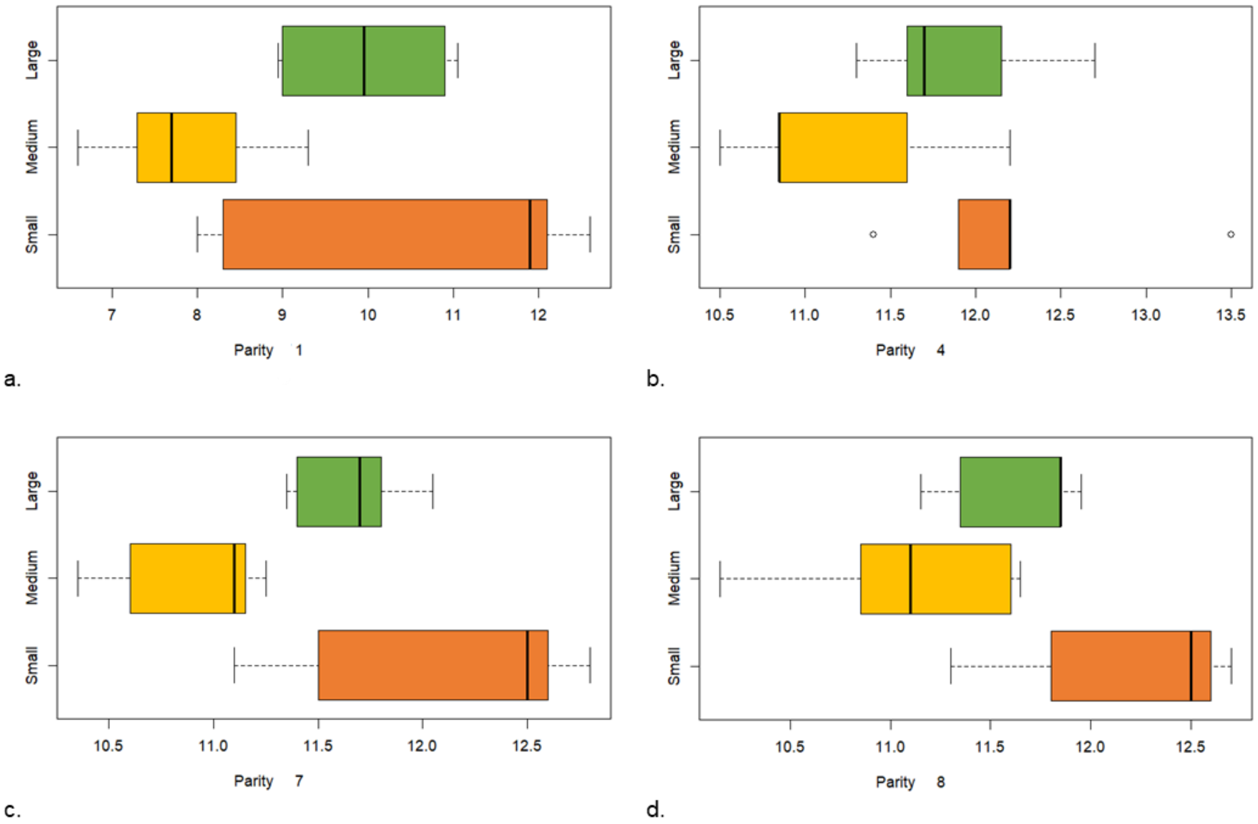

Figure 3.12 The average number of piglets weaned per parity on small, medium and large farms from 2017 to 2021

Furthermore, significant differences were established for various parities between small, medium and large farms which are summarizes in Table 3. Parities one, seven and eight had significant differences between small and medium farms as well as small and large farms whereas parity four only had a significant difference between small and medium farms. Parities two, three, five, six and nine had no significant differences.

Table 3.9 The Mann-Whitney U test results testing for significant difference for NPW between small, medium and large farms

Weaned Piglets Parity	Farm Size Comparisons	Test Statistic	P-Value
1	Small vs. Medium	4.0	0.095*
	Small vs. Large	10.0	0.690
	Medium vs. Large	23.0	0.032*
2	Small vs. Medium	12.5	1.000
	Small vs. Large	13.0	1.000
	Medium vs. Large	13.0	1.000
3	Small vs. Medium	9.0	0.548
	Small vs. Large	16.0	0.548
	Medium vs. Large	20.0	0.151
4	Small vs. Medium	4.0	0.09*
	Small vs. Large	8.0	0.402
	Medium vs. Large	19.5	0.172
5	Small vs. Medium	6.0	0.222
	Small vs. Large	11.0	0.841
	Medium vs. Large	20.0	0.151
6	Small vs. Medium	16.0	0.530
	Small vs. Large	11.0	0.834
	Medium vs. Large	9.0	0.548
7	Small vs. Medium	3.0	0.056*
	Small vs. Large	8.0	0.421
	Medium vs. Large	25.0	0.008*
8	Small vs. Medium	2.0	0.032*
	Small vs. Large	7.0	0.295
	Medium vs. Large	21.0	0.094*
9	Small vs. Medium	10.0	0.675
	Small vs. Large	16.0	0.526
	Medium vs. Large	15.0	0.690

*p-value<0.1

Due to incomplete records for WWP, NPS and SLAUW these traits were not analysed.

3.4 Discussion

In this study farm size had a significant effect for NBA, NSBP, NMP, NPW and MORT. It was found that small farms (<650 sows) had a higher level of NBA and NSBP which are similar to studies conducted in Macedonia and Spain (Angjelovski *et al.,* 2015). These studies found that small farms (<200 sows) had a higher average NBA compared to large farms (200-1000 sows) with 13.76 and 11. 98 respectively (Angjelovski *et al.,* 2015). In contrast to this study; studies in Poland (Angjelovski *et al.,* 2015; Dors *et al.,* 2013) and Ontario, Canada (Wilson *et al.,* 1986) show that large farms (>200 sows) have a higher average NBA compared to small (<50 sows) and medium (50-200 sows) farms (Koketsu, 2000a).

Moreover, studies comparing the different farm sizes have shown that small (1-500 sows) and medium (501-2000 sows) farms have the highest farrowing rate of 80-80%; however; large farms (2001 – 8000 sows) have the highest percentage (27%) of farrowing rate in the range of higher than 89% (Knox *et al.,* 2014). Large farms are followed by small farms with 24% and medium farms with 10% respectively (Knox *et al.,* 2014). It should be noted that for the latter, the large farm category for these coutries are similar to the small farm category in this study.

In this study it was also found that there was a significant difference for NBA per parity between farm sizes. There were significant differences in parity one, two, three, four, five, six, seven and eight between small and medium, medium and large and small and large farms. There is no literature available to support the effect of farm size on NBA in different parities however limited research was found on the average NBA found per parity (Klimas *et al.,* 2020). This study has also found that small, medium and large farms' NBA levels are highest in parities eight and nine respectively with parity one having the lowest for all three farm sizes. These results are similar to literature which has found that parity one experiences the lowest NBA (Klimas *et al.,* 2020). Sows first mating occurs at approximately 220 to 230 days old at which time they are not yet fully grown (Cottney *et al.,* 2012). Thus energy is expended not only on producing oocytes and preventing follicular atresia (King *et al.,* 1989) but also on growth of the sow, this limits the energy available for reproduction and therefore primiparous sows have a smaller litter size (Filha *et al.,* 2010). The parity with the highest level of NBA differs between this study as well as between literature which shows parities three and four having the highest level of NBA (Klimas *et al.,* 2020; Ye *et al.,* 2018).

The results of this study do not indicate the presence of second litter syndrome – the sows' production performance decreasing in the second parity due to the sows requiring to complete their growth and lack of body reserves after the first lactation (Kemp *et al.,* 2018). This indicates that the small, medium and large farms studied have supplied sufficient amounts of feed for both the completion of growth and maintenance of body fat reserves during the first lactation. This further emphasizes that management is a crucial factors as small, medium and large farms are all able to prevent second litter syndrome.

This study found that small farms have the highest average level of MORT with medium farms having the lowest. These results have similar (Wilson *et al.,* 1986; Koketsu, 2000a) findings indicating that small farms have a higher level of MORT compared to large farms (Angjelovski *et al.,* 2015). Moreover, a study has also shown that high-producing herds – majority of which have more than 800 sows and are considered large; have lower MORT compared to other herds (Koketsu, 2000a); which corresponds with this study's results. This can indicate that larger farms practice an earlier weaning and better management in the farrowing house (Wilson *et al.,* 1986). In contrast to this study's results, literature shows that MORT is higher in large farms with 13.85%, 13.74% and 13.18% for large, medium and small farms respectively (Dors *et al.,* 2013). In addition, large farms have been found to have MORT percentages for parities 1,2, 3-5 and ≥6 of 8.9%, 7.5%, 11.7% and 13.2% respectively (Koketsu, 2000a). Whereas the small herds have MORT of 10.8% 10.1%, 15% and 17.4% respectively (Koketsu, 2000a).

The three main causes of MORT in small medium and large farms are being laid on, low viability and being weak, being a runt and being too thin; and; being laid on being sick and having joint ill. An abundance of literature comparing disease prevalence on farms of different sizes indicates in some instance that small farms have a higher incidence (Tu *et al.,* 2015; Pettersson *et al.,* 2021; Pavia *et al.,* 2021) in comparison to large farms while others show the contrary (Wales *et al.,* 2013; Koketsu; 2000b). The majority of the main causes of MORT found in this study are not due to disease which indicates an effective biosecurity program has been implemented to curb entrance and spread of disease. However, this study shows that being sick is one of the top three causes of preweaning MORT on large farms and not on small or medium farms. Similarly, studies show that in all production stages that farms in the upper third in size have a mean that is at least twice as high as the farms with sizes in the lowest and middle third (Hemme *et al.,* 2018). This supports literature which shows that antibacterial treatment frequency is increased as farm size increases (Hemme *et al.,* 2018; Ström *et al.,* 2017) and also that large farms may have difficulty preventing disease due to them having to purchase lager numbers of gilts and having a higher number of specialized workers which do not have time to manage piglets which are showing clinical symptoms (Koketsu, 2000b). The presence of being sick being in the main causes of MORT may also be attributed to antibiotic and antimicrobial resistance (Tu *et al.,* 2015). Literature has found that antibiotic resistance has been found to be higher in medium (100-400) farms compared to small (<20) farms (Ström *et al.,* 2017).

In addition, this study has shown that the average percent of MORT due to being laid on in small farms is higher and has a wider distribution. The higher level of piglet crushing may be caused by less labourers available on the small farms or nursing units which are too large or too small for the sow and her suckling piglets.

Research conclusions with regard to NPW have been divergent as some indicate that small farms have a higher NPW compared to large farms with values of 11.98 and 10.88 respectively (Angjelovski *et al.,* 2015); and others state that larger farms have higher NPW (Koketsu, 2000a). This is caused by the diverse management practices that influence the level of production, these management practices were beyond the scope of the study.

This study has found that for small, medium and large farms parities four, six and two have the highest NPW respectively with large farms having higher averages for parities one, two three and nine. These results are similar to literature which has found large farms to have higher levels for parities one, two, three to five and more than and including 6 (Koketsu, 2000a). Possible reasons for the larger farms having higher levels of NPW include better piglet care, and better farrowing and nursing facilities and more frequent cleaning and sterilization of the area (Koketsu, 2000a). Furthermore, significant differences were found in this study between farm sizes for parities one, four, seven and eight.

Record keeping allows for effective management, identification of a problem, culling, costs and revenue (Koketsu, 2000a; Wilson et al 1986). Despite the complete records of NBA, NSBP, NMP, MORT and NPW; the incomplete records of WWP, NPS and SLAUW leave a gap in determining the success of the farm itself. The price of pork is determined by its quality (PORCUS) and by its corresponding weight (Hugo & Roodt, 2015) and therefore the NPS and SLAUW weight will determine the income. This indicates a need for farmers to enter records for the piglets from their birth until they are slaughtered to evaluate performance throughout the production process, determine areas which require improvement and to compare the costs of production with the income received.

Furthermore, literature has shown that covid-19 has had an impact on the livestock industry including a shortage of labour and closing of crucial processors in the industry (Bellini, 2021; Grandin, 2021). Covid-19 caused labour to be decreased in pig houses and processing plants up to 40-45% (Merchant-Forde & Boyle, 2020) with animals having to be euthanized (Baker *et al.,* 2019). This could explain a decrease in NBA and NPW for certain parities, MORT and MORT due to being laid on increase in the years of 2020 and 2021.

In summary, despite their being an abundance of literature discussing the use of genetics (Ye *et al.,* 2018; Hanenberg *et al.,* 2001; Matheson *et al.,* 2018), nutrition (Aherne & Kirkwood, 1985; Hasan *et al.,* 2019; Ferguson *et al.,* 2003) and management (Peltoniemi *et al.,* 2021; Rutherfod *et al.,* 2009; Anderson *et al.,* 2009) to improve sow performance, MORT and piglet survivability; there seems to be gap on the effect of farm size in commercial pork production.

This emphasizes the need to broaden the scope of research into different aspects such as management factors as this undeniably affects the productivity in commercial pig production in SA.

3.5 Conclusion

In conclusion, small farms had a higher level of NBA and NSBP and MORT. With regards to MORT, the main causes for death on small farms were being laid on, low viability and being weak; whereas on medium and large farms they were being laid on, being a runt as well as being too thin; and being laid on, being sick and having joint ill respectively. Small farms also had the highest percent of MORT due to being laid on. These findings are attributed mainly to the intensity of production and management factors. This study presented a benchmark of production in the SA commercial farms of different sizes. The findings show that small farms can be just as productive and efficient as large farms. This indicates that efficient production is possible for smallholder farmers despite their low number of sows.

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Chapter 4

A survey analysis on small holder pig farms in the North-west province

4.1 Introduction

In South Africa (SA), agriculture is characterised by a dual system containing highly developed commercial farmers and smallholder farmers farming on various levels across all livestock species, including pigs and poultry (Hall, 2004). Smallholder farmers exist on a spectrum ranging from market-orientated small-scale farmers to subsistence farmers (Zansti *et al.,* 2019) and thus defining these farmers allows for more accurately curated programmes (Zantsi *et al.,* 2019). There are approximately 3 million individuals that participate in subsistence agriculture in SA (Stats SA, 2021) with approximately 79 000 of them being in the North-west province (Stats SA, 2021). There is no available literature that reviews the percentage of smallholder farmers belonging to each livestock species, but rather the percentage of production of the smallholder and commercial farmers in each sector. Smallholder broiler farmers produce 25% of the total production (DAFF, 2017b). The informal beef sector contains approximately 43% of the national herd (Meissner *et al.,* 2013), smallholder sheep farmers hold approximately 13% of the stock (Cloete *et al.,* 2014), smallholder pig farmers contain approximately 30% of the national herd (BFAP, 2020) with informal goat producers owning 67% of the national stock (Meissner *et al.,* 2013).

In contrast to SA's smallholder pig production levels, the smallholder herds in both Tanzania (United Republic of Tanzania, 2021) and Kenya (Wabacha *et al.,* 2004) comprises more than 99% and 100% of the national herd respectively. Smallholder farmers play an important role in reduction of poverty (Diao *et al.,* 2010, Penrith *et al.,* 2013) by creating job opportunities (Mmbengwa *et al.,* 2015), enhance services rendered by commercial farmers (Zantsi *et al.,* 2019) and providing food for their households (Penrith *et al.,* 2013). Despite the ways in which smallholder farmers may improve both their family and community they still face challenges such as a lack of available genetic resources, infrastructure, nutrition and disease.

There is very little research available on the production of indigenous pig breeds of SA but the use of these breeds can aid the improvement of smallholder farmers as they are able to utilize food waste as a feed source and require a small amount of land for production (Halimani *et al.,* 2020). The infrastructure lacking by the smallholder farmers includes not only physical products such as roads, running water and electricity; but also includes knowledge of marketing and livestock management as well as money (Chaminuka *et al.,* 2008). The most common source of feed for smallholder farmers is swill (Amar *et al.,* 2021) due to commercial feed being expensive (Matabane *et al.,* 2015). Swill is not a source of feed only in SA but also in other countries such as India (Nath *et al.,* 2013) and Tanzania (Lipendele *et al.,* 2015) where other feed sources include mutard oilcake, banana, tapioca and sweet potato; and fruit, vegetables, sunflower or maize bran cakes respectively.

Moreover, disease is a limitng factor for smallholder farmers in SA (Sithole *et al.,* 2019; Janse van Rensburg *et al.,* 2020; Krecek *et al.,* 2012), Tanzania, (Lipendele *et al.,* 2015), Kenya (Mutua *et al.,* 2010) and India (Nath *et al.,* 2013). The two most common diseases found on smallholder farms are helminths (Sithole *et al.,* 2020) and African swine fever (ASF) (Janse van Rensburg, 2020) and smallholder famers are unable to identify presence of the disease in the meat post mortem and do not have knowledge about ASF.

In this study, demographic information and production traits were evaluated based on questionnaires collected from the North West province in order to provide suitable interventions for improving smallholder pig production. Limited research on smallholder pig farmers' production practices in South Africa is available. Therefore, this study about the small holders' production practices in the North West province allows for insight into the areas at which improvement is required to increase production as well as what the farmers deem important with regards to both constraints and improvements.

4.2 Material and Methods

4.2.1 Materials

This study was carried out with ethical approval (NAS262/2021) of the University of Pretoria research and ethics committee for the use of external data collected from smallholder farmers on behalf of SAPPO. The questionnaire was developed in collaboration with Mr Mothapo and Ms Senyatsi from SAPPO. Once confirmed as applicable, it was translated into Sestwana and can be found as Addendum E. The questionnaire included 11 sections to collect info on demographic information, household structure, herd structure, feeding and watering, housing type, marketing and culling, slaughtering practices, breeding, record keeping, areas of major constraints and areas of possible improvement.

4.2.2 Methods

The surveys were conducted during two workshops organised by SAPPO in the Northwest province. In addition, two market orientated farmers were visited. Farm visits were restricted due to ASF and the majority of the questions were completed during the workshop sessions.

Two workshops were organised by SAPPO with speakers who gave presentations to educate about biosecurity and genetic improvement for smallholder farmers. The Masters student gave a short presentation on basic pig production involving feeding, watering, housing and basic biosecurity measures. Following this the "take-home-bag" was given out to all the farmers and a production sheet was explained. The questionnaires were then distributed to the farmers and the questionnaire was filled in together, with the help of two Masters students. A total of 25 questionnaires were completed. The data collected was then typed into an excel spread sheet using headings and values representing the answers circled to prepare for the statistical analysis.

All data analysis was performed using a variety of packages using R Software (version 4.1.3; http://www.Rproject.org). Data analysis consists of descriptive statistics with measures including means, medians, standard deviations, frequencies, and proportions to describe the results. Continuous variables were described using means (with standard deviations and 95% confidence intervals or medians using interquartile ranges). Categorical variables were described using counts and percentages.

Fisher's Exact Test and Cramer's V Measure was utilized to determine if there was a relationship between certain variables (Kim, 2017). The use of Fisher's Test over the Chi-Squared test is due to the underlying assumption of the Chi-Squared test requiring a minimum count of 5 in each cell of a frequency table, which was not possible in this case due to the small sample size. If the resultant p-value of this test is less than 5%, the null hypothesis was rejected and it could be concluded that a relationship between the two variables were possible. In addition to the Fisher's exact test, odds ratios were calculated where applicable to obtain further statistical and numerical insights into the relationships between these variables of interest.

The hypothesis for Fisher's Exact test is as follows:

H_0: The variables are independent and there is no relationship between the two variables.

H_a: The variables are dependent and there is a relationship between the two variables.

Cramer's V is a statistical test which is used to understand the strength of the relationship between two variables if they're categorical in nature (Kim, 2017). In this case, all variables of interest were categorical and therefore satisfied this underlying assumption. This test can be used to evaluate the relationship between two variables (as is the case here), and when there are two or more unique values per category (which is also satisfied).

Cramer's V measures the strength of associated between two variables on a scale ranging from 0 to 1, where 0 indicates no association between the variables and 1 indicates a perfect association between the two variables. The disadvantage of the Cramer's V measure is that there is no indication of specific relationships between the two variables. This prevents the construction of a more complete argument for relationships identification between the two variables of interest.

It is calculated in the following manner:

$$\text{Cramer's V} = \sqrt{\frac{\left(\frac{\chi^2}{n}\right)}{\min(c-1, r-1)}}$$

Where the degrees of freedom are determined by: min (c-1, r-1). Tables and pie charts were then created using R studio with both the descriptive statistics results as well as the results from the Fisher's Exact Test and Cramer's V Test. The process followed is summarized below in Figure 4.1.

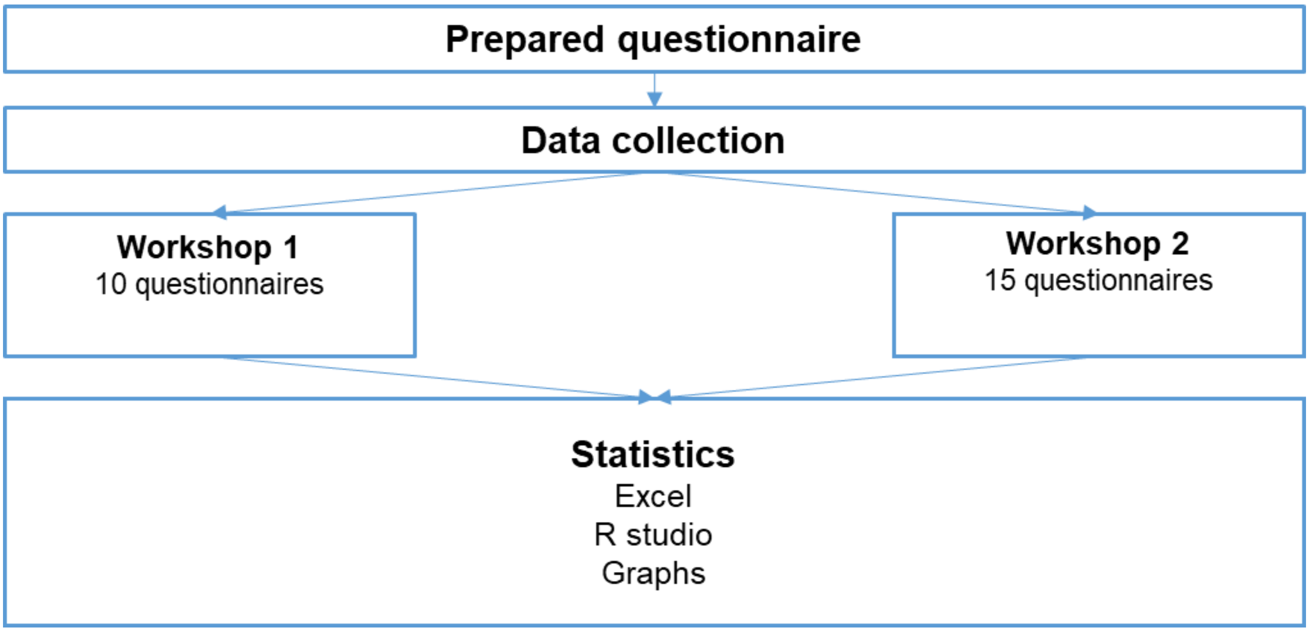


Figure 4.1 The steps taken in order to complete the analysis of the questionnaires collected

4.3 Results

4.3.1 Demographic Information and household structure

The 25 respondents represented 14 villages with the majority of the respondents coming from Jouberton (20%) and Khuma (20%) with the other villages each having 4%. The villages are displayed below in Figure 4.2.

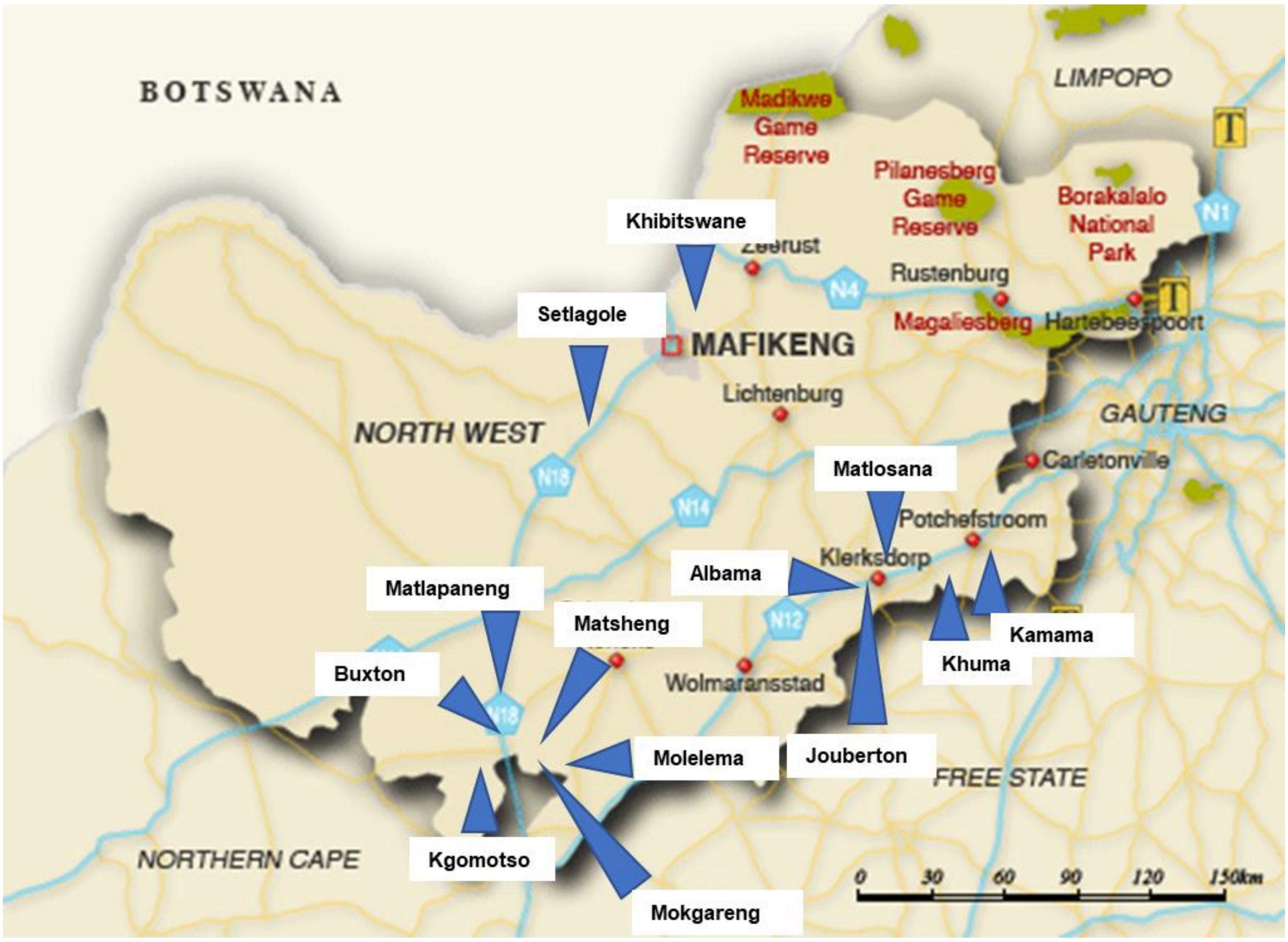
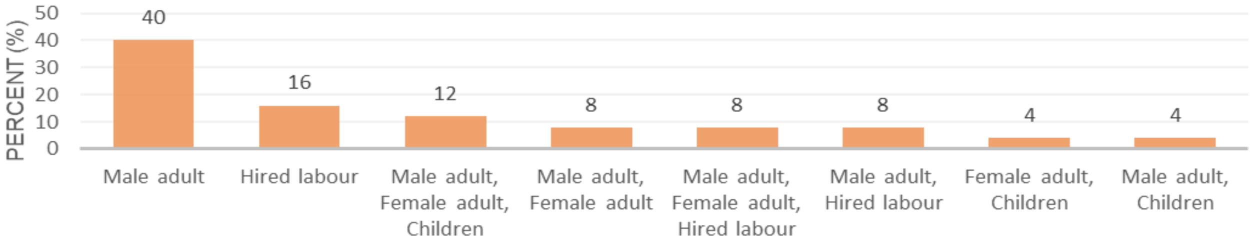


Figure 4.2 Map displaying the respondents' villages

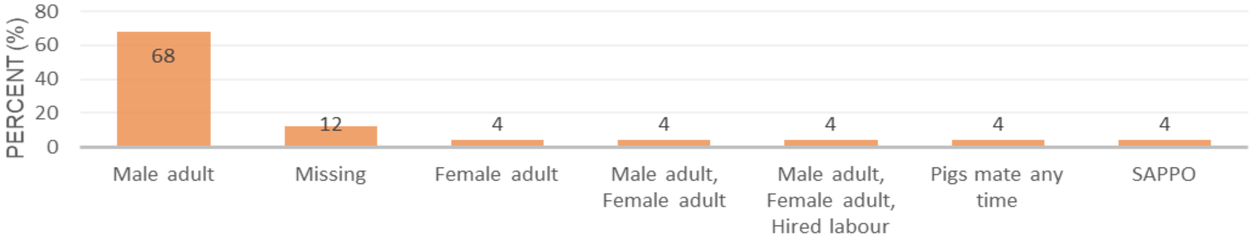
48% of the respondents owned their own land with 24% leasing and 20% using communal farming and a grandparent owning the land with 4%. The head of the household were mostly males (76%) with females in the minority (24%). In addition, it was found that the animals were owned primarily by individuals that were parents (72%), followed by other (12%), a child (8%), the community (4%) or by grandparents (4%). The age of the owners of the animals were largely in the age range of 45-60 (56%), followed by 30-45 (20%), older than 61(16%) and 18-30 age range having the lowest number of farmers (8%).

The level of education of the respondents was primarily secondary school (48%), followed by tertiary (28%), primary (12%) and 8% had no education. It was found that 88% of respondents used pig farming as their primary source of income, 16% used crops, 44% used livestock products, 40% used salary or wages and 16% used other sources of income.

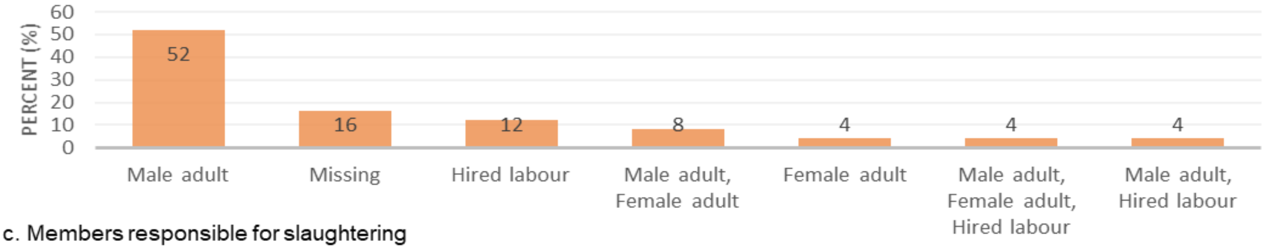
This study was directed at pig farmers and so all the respondents have pigs which were either bought (78%), exchanged (3.7%), received as a gift (3.7%), inherited (3.7%) or originated in a non-disclosed way (7.4%). However, the keeping of other farm animals was also studied. It was found that respondents kept goats (40%), sheep (28%), chickens (56%), cattle (60%), donkeys (4%) and other animals (12%). The percent of the members of the household responsible for the various pigs' activities such as feeding, breeding, slaughtering, selling, purchasing, animal health and other were also analysed. It was found that the pig activities were the responsibility of one person or a combination of people. This is displayed below in Figure 4.3.



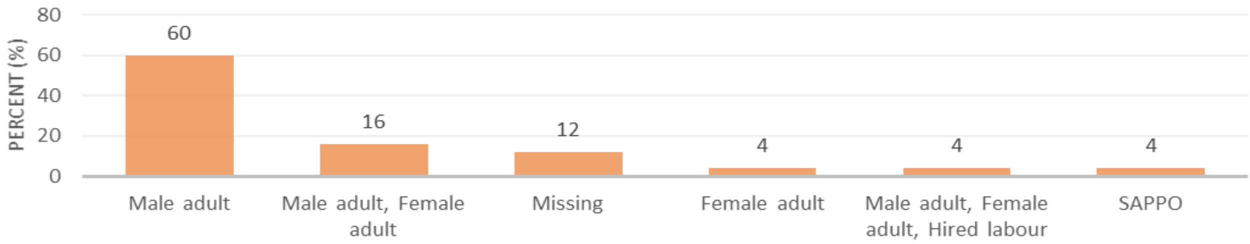
a. Members responsible for feeding



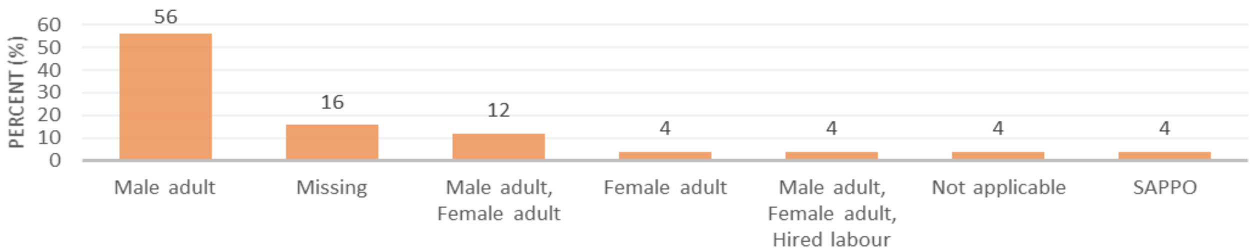
b. Members responsible for breeding



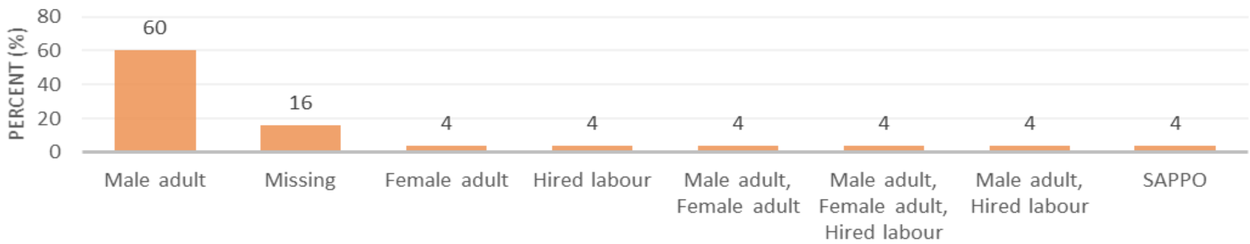
c. Members responsible for slaughtering



d. Members responsible for selling



e. Members responsible for purchasing

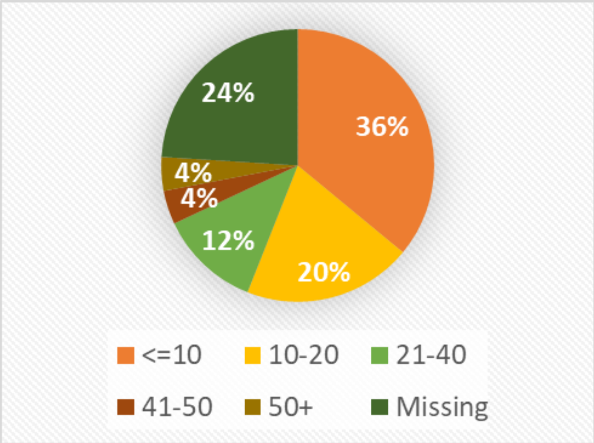


f. Members responsible for animal health

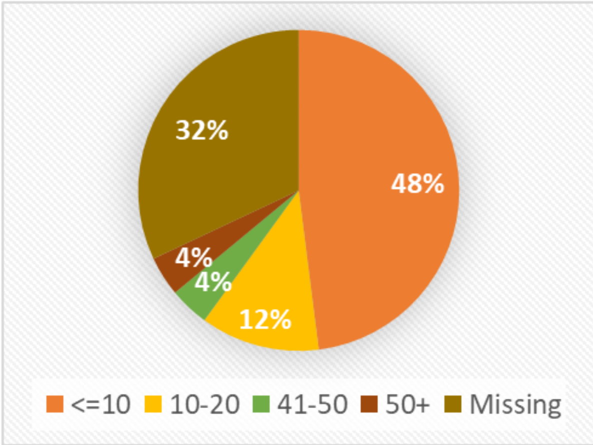
Figure 4.3 Members responsible for pig activities

4.3.2 Herd structure

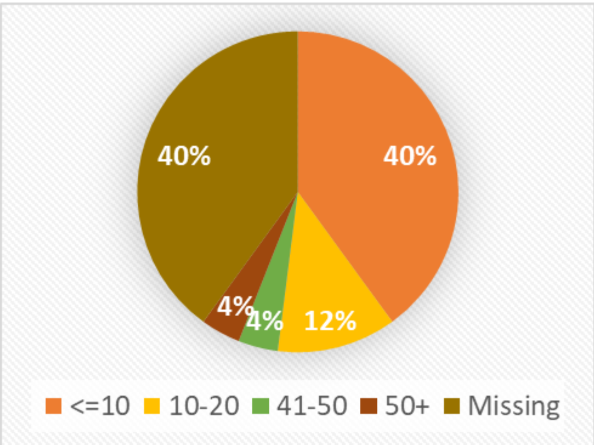
The number of pigs kept in each stage of production were investigated which indicated that most of the farmers had 10 or less pigs in each production stage. The herd structure is shown below in Figure 4.4 below.



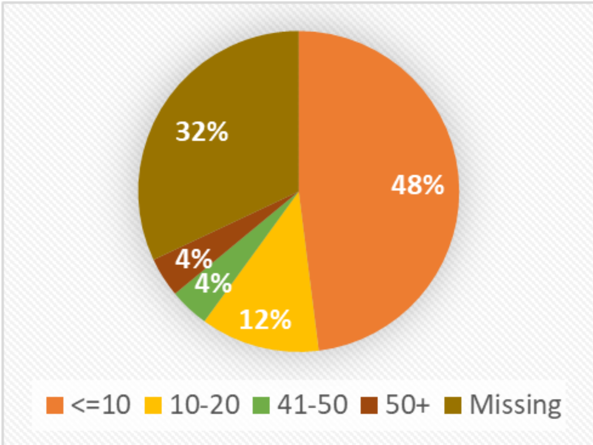
a. Number of piglets kept (<6 weeks)



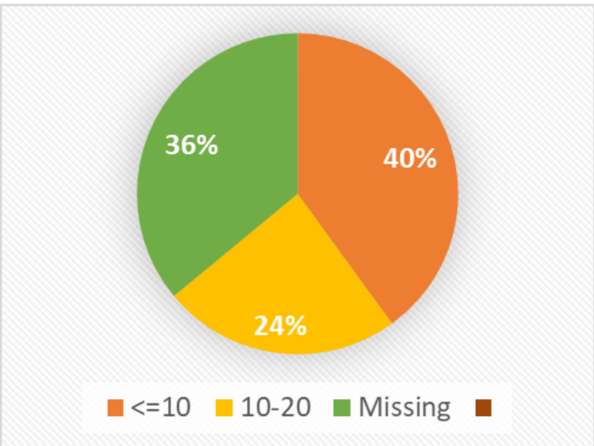
b. Number of weaners kept (6-10 weeks)



c. Number of growers kept (10-16 weeks)



d. Number of growers kept (5-12 months)



e. Number of baconers/finishers kept (17-22/24 weeks)

Figure 4.4 The herd structure of pigs kept

Furthermore, the percentages of keepers keeping different ranges of sows is found in Figure 4.5.

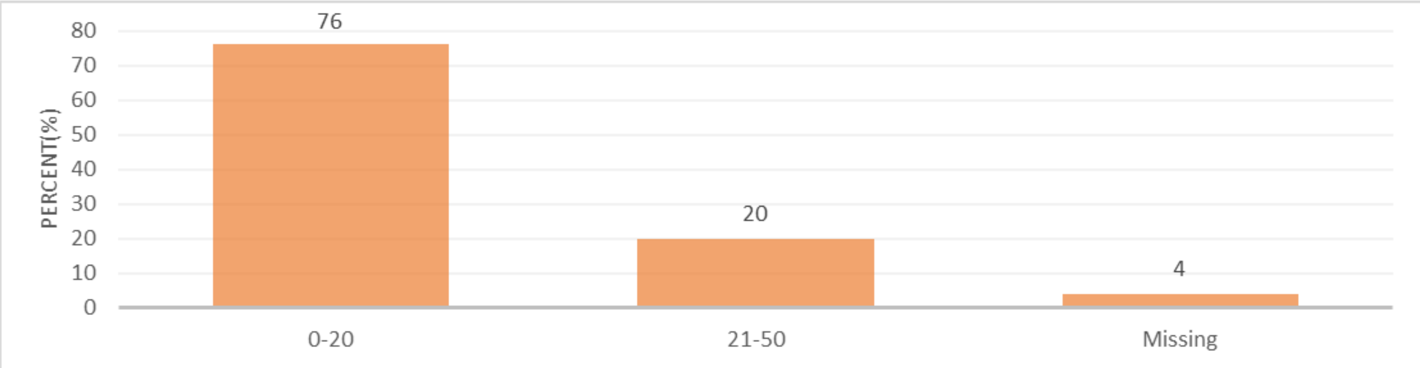


Figure 4.5 Percentage of farmers keeping different number of sows

It was found that 52% of the pig keepers have a boar and of those that have a boar, 60% have one, 26% have two and 7% have 6. In addition, it was found that 84% of keepers used natural mating, 0% used artificial insemination only while 12% used both. 48% of the pig keepers' pigs ran with other animals.

4.3.3 Feeding and watering

In Figure 4.6 below the different feed and water sources are displayed. Some of the respondents are using more than one feed and water source.

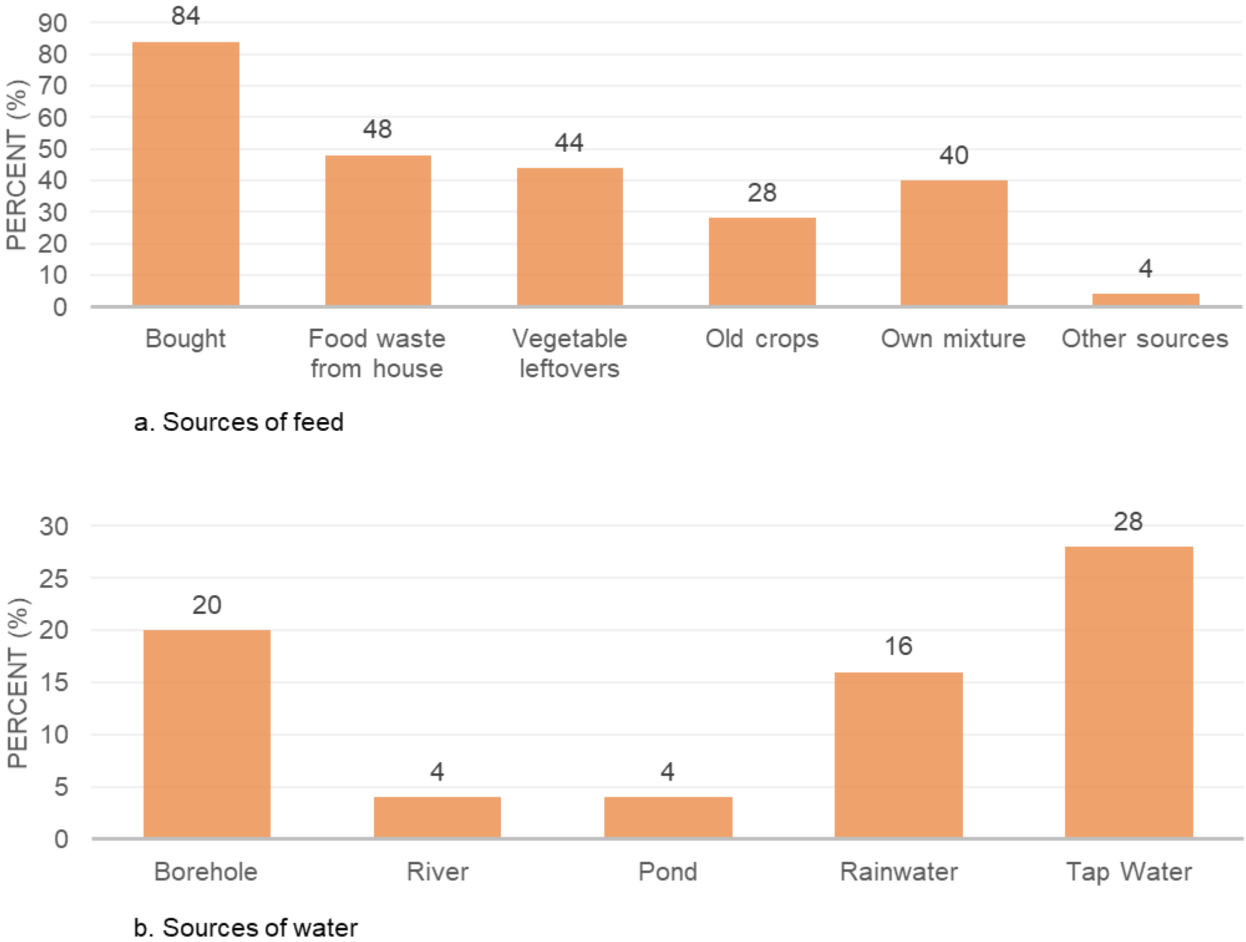


Figure 4.6 Sources of feed and water

Water is a limited resource and it was found that not all pigs receive water *ad libitum*.

4.3.4 Housing

Based on the questionnaires 72% of the pig keepers' had pig housing in the form of a kraal, stall/shed or closed housing. Sixty % had different houses for different production stages. The housing methods utilized in winter and summer are displayed below (Figure 4.7).

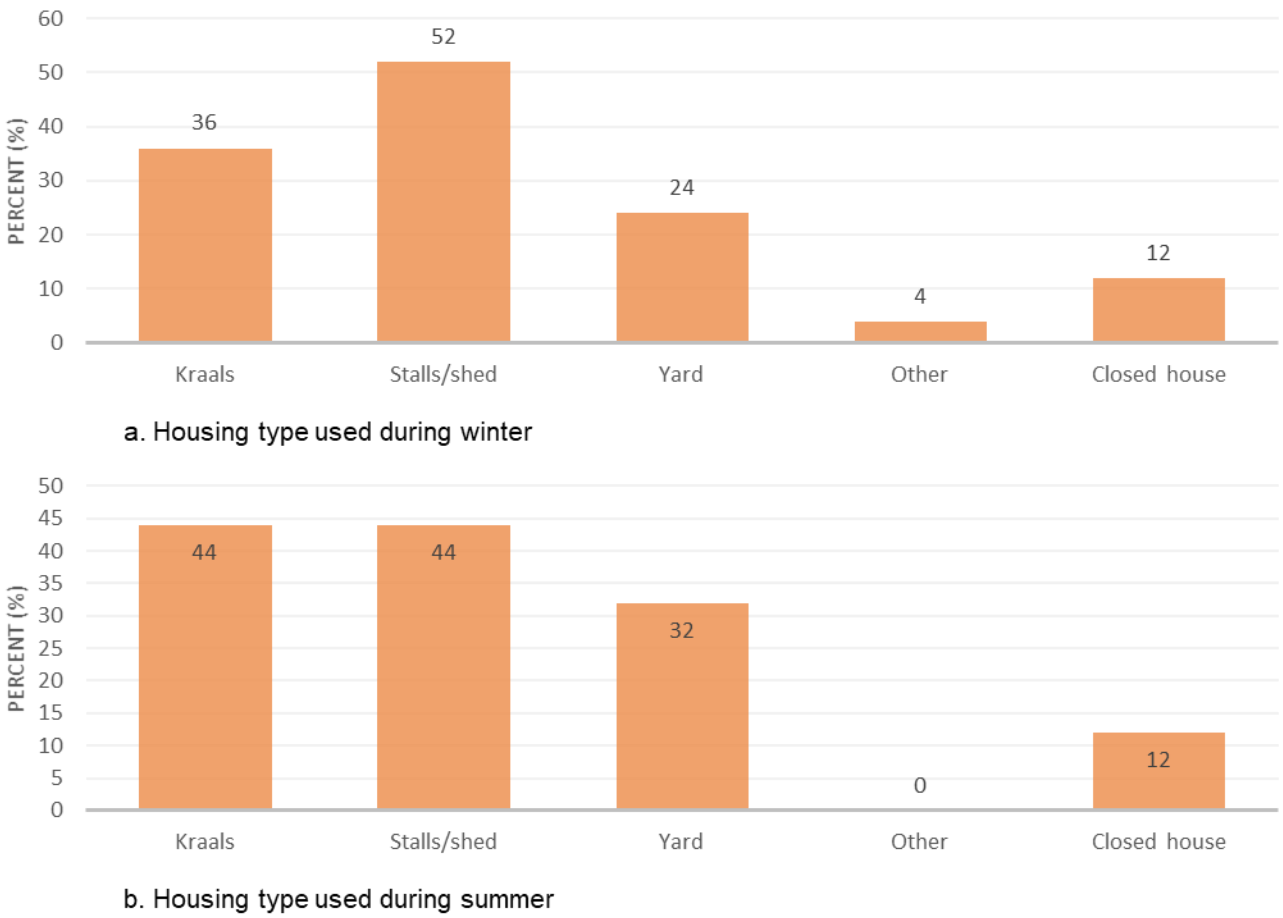


Figure 4.7 Housing methods utilised in winter and summer

The percentage of pig keepers that have utilized different type of floor and walls can be found in Table 4.1.

Table 4.1 Percentage of farmers using different types of floors and walls.

Type of floor or wall	Proportion	Frequency(64%)
Roofed house	16	64
Solid walls	13	52
Concrete floor	16	64
Wooden floor	1	4
Earth floor	12	48

Furthermore, the materials used by the keepers to build their houses was also included in the questionnaire and analysed. These results are in Table 4.2.

Table 4.2 Percentage of farmers using different materials to build their pig houses

Materials used	Proportion	Frequency(%)
Wire	7	28
Mud	2	8
Bricks	14	56
Untreated wood	4	16
Treated bush	2	8
Iron sheets	18	72
Other	1	4

It was also found that water was supplied using a trough for 68% of the respondents and through a nipple for 12%.

4.3.5 Marketing and Culling

The marketing and culling section of the questionnaire yielded responses indicating that 72% of the pig keepers cull their animals. The reasons for culling are summarised in Figure 4.8.

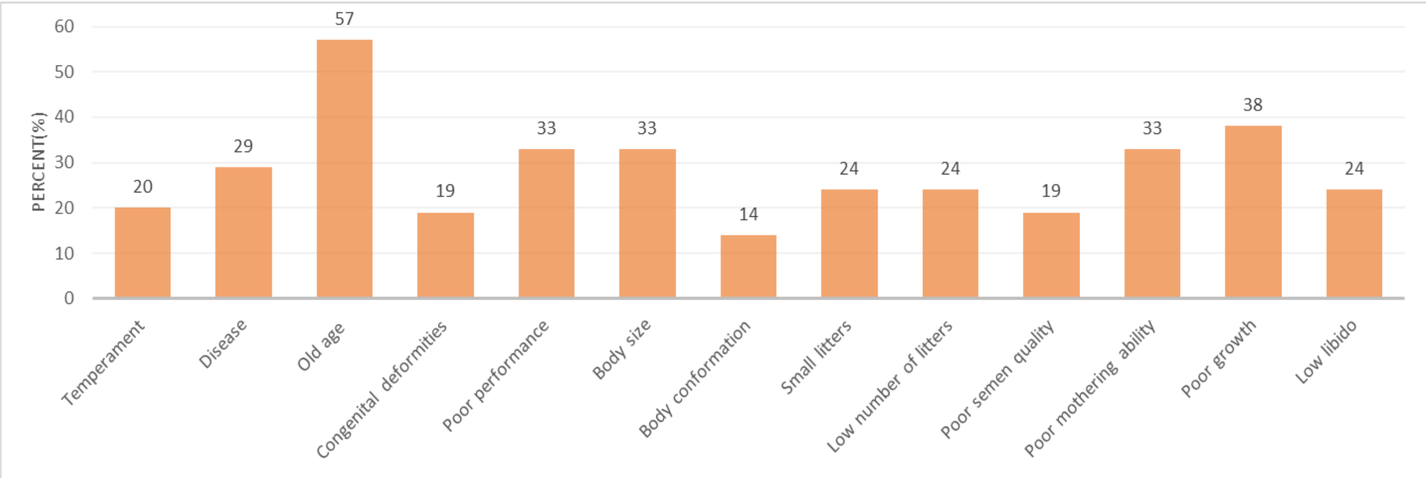
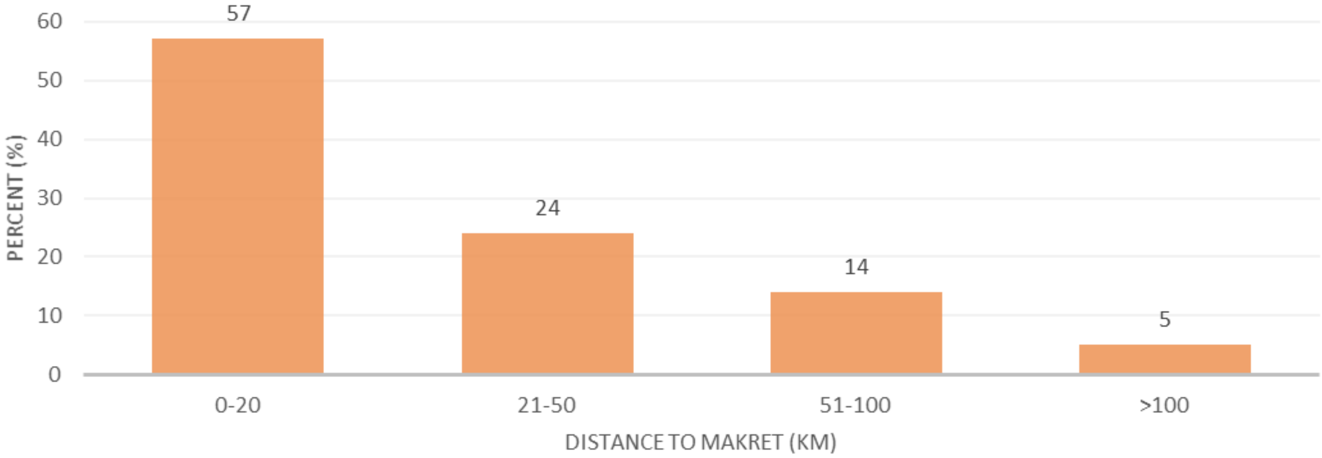


Figure 4.8 Reasons for culling

Additionally, it was also found that 84% of the pig keepers sell their animals. When the farmers sell, to whom they sell and the distance to market is displayed (Figure 4.9).

a. When the farmers sell the animals

b. To whom the farmers sell



c. Distance to market

Figure 4.9 Overview of selling practices

The pigs sold by the farmer include males (36%), females (5%) or both (59%) and being of the different ages in Table 4.3.

Table 4.3 The percentage of farmers who sell pigs at different ages

Age of pigs	Percent of farmers (%)
<6 months old	33
7-12 months old	52
12-18 months old	20
18-24 months old	8
24-36 months old	10
>36 months old	10

The results of the questionnaire discovered varied results and questions about slaughtering were not fully completed. Thus results should be interpreted with caution.

4.3.6 Production

Fifty two % of the respondents completing the survey indicated that they use a boar from their own herd. While 32% of pig keepers purchase boars from commercial, stud breeders or auctions. The majority of the boars used are Large White, followed by Landrace and Camborough. Indigenous breeds such as Kolbroek represents 4% and 28% of the pig keepers could not positively identify the breed they are farming with. Most of the respondents keep their boars for 2 to 4 years before they are replaced. The farmers rated their pigs based on a number of traits with a scale of “poor”, “average” and “good”. These results are summarized below in Table 4.4 below

Table 4.4 Percentage of farmers who assigned their pigs a rating of poor, average or good

Trait	Male			Female		
	Poor	Average	Good	Poor	Average	Good
Growth rate	4	36	52	4	24	60
Body size	4	40	48	0	36	48
Body conformation/ size	4	28	56	4	36	48

It was found that 44% of pig keepers perform record keeping. The points recorded are displayed below (Figure 4.10).

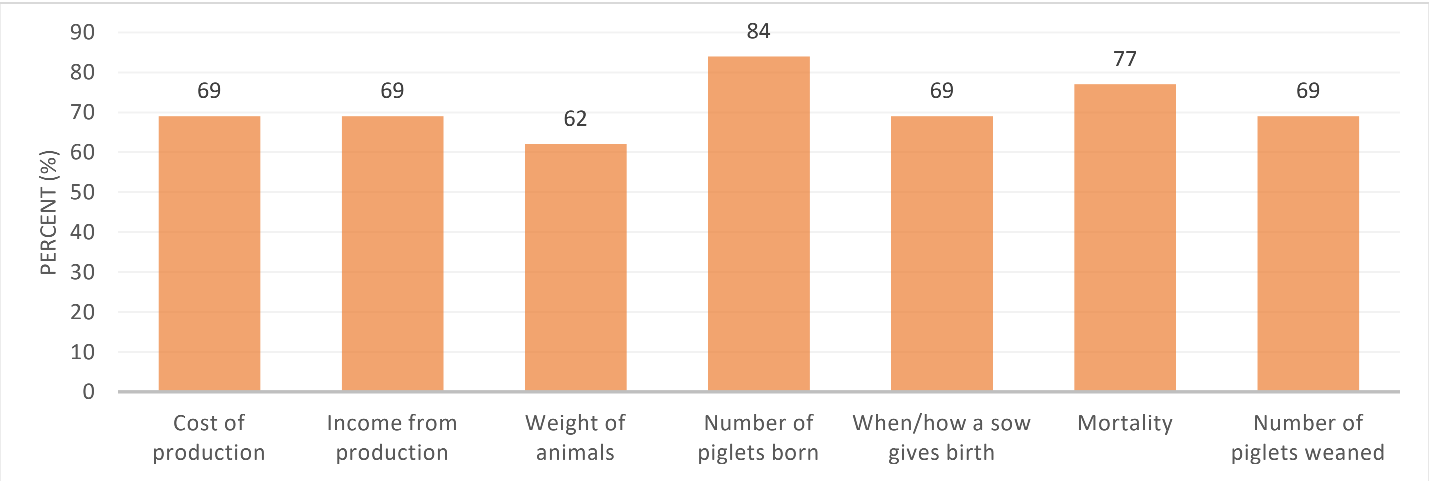


Figure 4.10 Recording of production parameters by the farmers

Of the respondents that didn't record, 23% said it was due to cost and 77% said due to other reasons.

In addition, 84% of pig keepers identify their pigs and used ear tags (36%), tattoos (28%), both (20%) or none (12%). Of those that do not identify their pigs; 60% said it was due to costs while 20% said it was not accessible and 20% said it was due to other reasons.

4.3.7 Constraints experienced by the farmers and areas of possible improvement

The last two questions of the questionnaire were relating to each pig keeper's experiences and therefore was an open-ended question to which the farmers could provide more than one response. The constraints and areas of improvement stated by the farmers in Tabels 4.5 and 4.6 respectively.

Table 4.5 Constraints experienced by the farmers

Constraint	Frequency	Proportion (%)
Feed cost	7	13.46
Proper housing resources	7	13.46
Disease and hygiene and cost thereof	5	9.62
Money	5	9.62
Stock theft	5	9.62
Space for the farming	4	7.69
Access to markets	3	5.77
Breeding stock	3	5.77
Shortage of feed/water	3	5.77
Burning of the veld	2	3.85
Lack of knowledge	2	3.85
Communal land	1	1.92
Drainage system - can't keep house or area clean	1	1.92
Lack of good management	1	1.92
More staff	1	1.92
No petrol	1	1.92
Answer missing	1	1.92

Table 4.6 Areas of possible improvement as stated by the farmers

Areas for improvement	Frequency	Proportion (%)
Genetics	7	13.46
Housing and transportation	6	11.54
Management	5	9.62
Security	5	9.62
Access to vets and biosecurity	4	7.69
Access to workshops and training / SAPPO	4	7.69
Health/disease	4	7.69
Funds	3	5.77
Own housing and space	3	5.77
Automation	2	3.85
Feed/water access	2	3.85
Veld fires	2	3.85
Boxfeeders for less waste	1	1.92
Food	1	1.92
Marketing	1	1.92
Missing	1	1.92
More staff	1	1.92

Due to the limited questionnaires collected relationships between variables were statistically inconclusive.

4.4 Discussion

4.4.1 Demographic information and household structure

This study was based on a questionnaire of pig keepers in the Northwest province, more specifically Mafikeng, Taung and Klerksdorp. Land ownership is similar to the study of Matabane *et al.,* (2015), conducted in the Gauteng province, who also reported that the most of the small holders owned their land, while others either leased or made use of communal land.

The majority of the head of the households and farmers were males, similar to studies conducted in Gauteng (Matabane *et al.,* 2015) and Mpumalanga (Munzhelele *et al.,* 2017) in SA as well as Tanzania (Kimbi *et al.,* 2015), Democratic Republic of Congo (DRC) (Kambashi *et al.,* 2014) and India (Nath *et al.,* 2013) which had levels of 67%, 54%, 85% and 64% respectively. In a study conducted in Eludini, Eastern Cape and Cambodia contrasts this as majority of the farmers were women (Madzimure *et al.,* 2013; Ström *et al.,* 2017). Kenya shows varying results as some studies indicate a male dominated industry while others indicate a female (Mutua, 2010; Kagira *et al.,* 2010). The majority of the repondents were mainly between the age of 45 to 60 which is also confirmed in studies conducted in Gauteng (Matabane *et al.,* 2015) and Eastern Cape (Madzimure *et al.,* 2013). A study by Munzhelele *et al.,* (2017) reported that 78.7% of the farmers were aged 40. Overall the current study and literature indicate that young people's interest and participation in farming is limited with their interests and employment being in larger urban areas (Tada *et al.,* 2012).

The highest level of education of the pig keepers in this study was mainly secondary school which is similar to a study conducted in Gauteng (Matabane *et al.,* 2015). There seem to be differences among provinces as studies conducted in the Eastern Cape and Kenya indicated primary education as the highest level of education (Madzimure *et al.,* 2013; Kagira *et al.,* 2010). In addition, studies conducted in Limpopo province and Tanzania (Kimbi *et al.,* 2015) found that approximately 18% had no formal schooling, 54.1% completed grades one to eleven, 18.2% completed grade twelve and less than 10% had tertiary education (Munzhelele *et al.,* 2017).

Eighty eight % of the keepers used pigs as their main source of income with 40% having a salary or wages which is similar to a study conducted in the Eastern Cape in SA (Madzimure *et al.,* 2013) and the DRC (Kambashi *et al.,* 2014). Pig farming seems to be male dominated based on this study with male adults being responsible for feeding, breeding, slaughtering, selling, purchasing and health decisions. This directly contrasts a study in the Eastern Cape in the town of Ntabankulu which found women responsible for many management practices, with the men performing the slaughtering and building of the houses (Madzimure *et al.,* 2013). Furthermore, this study has found that hired labour usage ranges between 4% and 16% by either using only their service or in conjunction with male and female adult family members; this information is pertinent as the farmers are trusting hired labour to maintain the management requirements. The low levels of production may be due to hired labour not fulfilling the requirements of the farmer – and not fulfilling the potential of the animals.

4.4.2 Herd structure

Herd sizes in the North west province are small and vary between 0 and 20 sows. In provinces such as Mpumalanga (Munzhelele *et al.,* 2017), Eastern Cape (Madzimure *et al.,* 2013), the Western Cape (Molotsi *et al.,* 2021), Kenya (Kagira *et al.,* 2010), Cambodia (Ström *et al.,* 2017), the DRC (Kambashi *et al.,* 2014) and Tanzania (Kimbi *et al.,* 2015) herds are of similar size. Only 24% of farmers in this study had more than 20 sows with maximum of 50.

Most of the respondents had less than 10 animals in all stages of production which is similar to a study conducted in the Western Cape (Molotsi *et al.,* 2021). Fifty two % of farmers have a boar with most having either one or two, which corresponds with a study showing the average number of boars between 2.3 ± 2.16 (Molotsi *et al.,* 2021).

The pig keepers in the North west mainly used a breeding boar from their own herd however this is in contrast to other SA and Kenyan sources which found that majority of the respondents either bought or borrowed their breeding boars (Madzimure *et al.,* 2013; Molotsi *et al.,* 2021; Kagira *et al.,* 2010) or, source their boars from auctions (Munzhelele *et al.,* 2017; Matabane *et al.,* 2015). The use of boars from their own herd as breeding stock will cause a high level of inbreeding within the herd and thus lead to a decrease in production performance and health of the animals. The boars used for breeding were kept mainly between 2 to 4 years and nearly half of them were bought – mainly from a commercial farmer.

4.4.3 Feeding and Watering

The feeding sources of the farmers in the North west province show similarity to certain other studies conducted in various parts of South Africa, Tanzania, Kenya and India (Molotsi *et al.,* 2021; Janse van Rensburg *et al.,* 2020). However, other studies in SA, the DRC, Kenya, Tanzania and India show the contrary (Matabane *et al.,* 2015; Molotsi *et al.,* 2021; Lipendele *et al.,* 2015; Kagira *et al.,* 2010; Kambashi *et al.,* 2014; Nath *et al.,* 2013; Kimbi *et al.,* 2015). In South Africa, if swill is utilized as a feed source, the farmer is unable to sell to commercial abattoirs for slaughter. This therefore limits the small holders entrance to the commercial industry and certifies a divide between the smallholders and commercial industry.

Despite various studies analysing and reporting on the various aspects of the feed utilized by the farmers, few literature sources discuss the watering of the pigs. Water is essential for both growth and reproductive performance and therefore the absence of water can cause irreparable damage to the production levels of the animals (Komlatsky *et al.,* 2022). The provision of water is not focused on enough in literature concerning small holder farmers.

4.4.4 Housing

Sixty four % of respondents in the North west had roofs on their houses, 52% had solid walls, 64% had concrete floors, 4% had a wooden floor and 48% had earth floors which are similar to other studies (Molotsi *et al.,* 2021). Furthermore, a Tanzanian study found that 95% of farmers had a pig shelter with half of the respondents having earth floors and the other utilizsing raised slatted wooden floors (Kimbi *et al.,* 2015). Studies in Kenya indicate the majority of farmers use no housing while 36% of them use timber walls and thatch roofs (Kagira *et al.,* 2010) and majority of smallholder farmers in Cambodia utilize only pens (Ström *et al.,* 2017). The pig keepers utilised different housing types in winter and summer but extensive and semi-intensive remained the most used production system which is similar to a study which found semi intensive and extensive housing to be in higher percentages than intensive housing (Munzhelele *et al.,* 2017). There are studies which contrast this which found that majority of the respondents practiced intensive farming with the use of closed, environmentally controlled housing (Matabane *et al.,* 2015; Molotsi *et al.,* 2021).

This study found that iron sheets, bricks and wire mesh being the most used housing material which is similar to other studies (Matabane *et al.,* 2015; Molotsi *et al.,* 2021). In contrast to this the most utilized materials in Tanzania and India are wood off cuts, thatch grass and iron sheets (Kimbi *et al.,* 2015; Nath *et al.,* 2013). The use of the iron is due to it being able to prevent rain from entering the house while not eroding over time and the use of wood is due to its lower cost as well being used for multiple functions (Molosti *et al.,* 2021).

4.4.5 Marketing and Culling

The pig keepers in the North west practice culling for various reasons which could indicate that the farmers understand the use of the culling to seek constant levels of production for either home consumption or as a source of income. Furthermore, majority of the respondents sold their pigs with majority selling when available. These findings are similar to those of a study conducted in Gauteng (Matabane *et al.,* 2015). The pig keepers are not currently sustainable which is observed in the low number of pigs in all production stages. 62% of respondents sold their pigs directly to the consumer which is similar to numerous studies (Madzimure *et al.,* 2013; Molotsi *et al.,* 2021). However, this study's results differ to another study which found that majority of farmers sell at auction (Matabane *et al.,* 2015). Due to the respondents being unable to maintain a consistent production and the use of swill; they are unable to sell to an abattoir on a constant basis or at any time and thus rely on selling to consumers directly.

Majority of the pig keepers' in the North west markets are between 0 to 20km with majority of the animals sold including both males and females. With majority of the respondents selling directly to their consumers, the distance to their market will be shorter and thus the source of their breeding boars are limited. Furthermore, majority of the pigs sold are both followed by only males, this corresponds with the use of female weaners or growers or gilts being used as breeding stock instead of being sold. Furthermore, majority of the animals sold were of age 7-12 months old, which differs to those in other studies which indicate that majority of the pigs sold are weaners (Molotsi *et al.,* 2021). Due to majority of the pig keepers selling when they need extra cash or when they can, this leads to the animals being sold at the age of the pigs at that time.

4.4.6 Production

Most respondents indicated that they use Landrace which is similar to various studies. Contrasting this study, a study in the Eastern Cape found that majority of the respondents utilized indigenous breeds (Madzimure *et al.,* 2013; Halimani *et al.,* 2012). In contrast, the pig breeds and lines that the commercial producers in South Africa use are not indigenous breeds but rather exotic breeds. Should the smallholder farmer want to assimilate into the commercial industry exotic breeds should be considered instead of the indigenous, due to higher production.

The respondents also rated their pigs using the scale poor, average or good. Majority of the traits assigned ratings did not receive a high percentage of poor rankings. The higher ranking given to the pig keepers' pigs could indicate that the farmers do not have the knowledge of the possible level of production that their farm could achieve. Fourty four % of the respondents keeps records of various production parameters. Such results are similar to analyses conducted in the Western Cape and Gauteng which found that approximately half of their respondents practiced record keeping (Molotsi *et al.,* 2021; Matabane *et al.,* 2015), with the respondents focusing on the date that piglets were born, the number of pigs owned at a particular time and when to breed.

Moreover, majority of the pig keepers identify their animals and mainly with ear tags which is similar to other studies (Molotsi *et al.,* 2021). However, another report has shown that more than half of their respondents did not identify their animals (Matabane *et al.,* 2015).

4.4.7 Constraints experienced by the farmers and areas of possible improvement

This study has found that the five most common constraints are cost of feeds, adequate housing resources, disease and hygiene and cost thereof and stock theft. The constraint of the cost of feed provides an explanation of the substantial percentage of respondents who utilize swill as a feed source. This also allows for researchers to understand the pig keepers' decisions on farm. Unfortunately, until the pig keepers are able to provide feed in a way that does not include swill, abattoirs will not buy their pigs for slaughter and thus pig keepers will not be able to enter the commercial industry. Furthermore, the cost of feed, housing resources and cost of disease prevention fall under the spectrum of infrastructure. It has been found in literature that infrastructure directly influences the growth of the market which in turn makes the development of infrastructure possible (Chaminuka *et al.,* 2008). Thus the development of infrastructure should be one of the main focuses on ways to benefit the pig keepers and smallholder farmers.

Many of the options available to curb entrance and spread of disease include foot baths however simpler and cost effective ways can be implemented namely: cleaning up faeces and keeping the area clean, use soap to wash hands prior to entering, and handling the sick animals only after handling the healthy. Many of these methods mentioned require a change in management that can have a significant influence on the level of disease on the farm. Pig keepers may require costly medication from veterinarians, however if many of the farmers in the community are facing the same problem, it may be possible to buy the medicine in bulk and at a cheaper price. Thus, working as a community to have a less disease prevalent farm should be the goal. Furthermore, having a more cohesive community where knowledge and vigilance is shared may lead to less stock theft. As the pig keepers improve their farms together, the community of pig keepers will grow and thus the community surrounding them does as well.

The farmers aspiring to improve their genetics would like to buy exotic breeds from commercial companies. However, literature has shown that the use of indigenous breeds may support smallholder farmers (Halimani *et al.,* 2010). The indigenous pig breeds are able to utilize a smaller land to accommodate a larger population, to utilize crop residues and vegetables as a feed source, are less prone to becoming heat stressed, are more resistant to diseases and parasites compared to the exotic breeds (Halimani *et al.,* 2010; Madzimure *et al.,* 2013, Zanga *et al.,* 2003). Thus the use of these pigs can lead to a secure food source and level of income (Halimani *et al.,* 2020) without the need for building an intensive piggery. However, the use of indigenous pigs must not lead to an increase in inbreeding. Studies have shown a high level of inbreeding already within the indigenous breeds (Halimani *et al.,* 2012) however inbreeding can be decreased with adequate breeding programmes as well as education on preventative measures (Mutua *et al.,* 2010).

Housing and transportation are seen as the main constraints and areas of improvement which emphasizes the farmers' requirement for adequate resources and amenities available. Literature shows that if infrastructure is more available to the farmers, the farmers will readily employ these amenities which will create an opportunity for production to increase (Kamara, 2010). The last main area for improvement is management. This area encompasses many aspects such as feeding, watering, cleaning, breeding and record keeping.

4.5 Conclusion

There are various common areas of possible improvement found in genetics, housing and transportation and management. These areas of improvement emphasize that all smallholder pig farmers are different, experience different struggles and require different solutions.

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Chapter 5

Discussion and conclusions

The aim of this study was to evaluate the smallholder pig farmers of the North west province but it was deemed necessary to benchmark the commercial industry in order to discuss how the smallholder farmers will be able to enter the commercial market. However, as this study progressed it became more clear that the respondents of this study are pig keepers and not smallholder farmers who are market-orientated.

The data utilised to benchmark the commercial industry was received from a commercial company. The descriptive analyses of three different farm sizes namely small, medium and large production norms and trends for traits were similar to other studies. It was found both this study and literature that small farms had a higher level of average number of piglets born alive (NBA) and average number of piglets stillborn (NSBP). Significant differences between parities one, two, three, four, five, six, seven and eight were found between small, medium and large farms with regard to NBA. The sows recorded in this study did not show any signs of second litter syndrome. Moreover, medium farms were found to have the lowest level of mortality (MORT) and small farms were found to have the highest level of MORT. These results are supported by international literature. The most common cause of death between the different sized farms differed except for being laid on by the sow being prevalent in all three. However, small farms were found to have the highest percent of MORT due to being laid on. In addition, it was also found that average number of piglets weaned (NPW) for parities one, four, seven and eight showed significant differences between small, medium and large farms. The results indicate that small farms are able to maintain similar production levels to those of the large farms, this emphasizes that management impacts production greatly.

The commercial farms analysed, all utilize intensive housing which directly contrasts the pig keepers of the North west province. These farmers are mostly backyard pig keepers who aspire to improve their production levels either to sustain their family or to sell to a market. Majority of the respondents owned their own land, male dominated with male adults performing many of the pig keeping responsibilities; and were aged between 45 to 60. This indicates a poor interest of the younger generation in the use of pig farming as income or provision of food for their family. Literature also supports this study's findings that majority of the farmers owned between 0 and 20 sows, had less than 10 animals in each production stage, had one or two boars and used natural mating. These findings indicate the pig keepers' inability to maintain a sustainable production level. Many factors come into play here however management is one of the most crucial factors lacking.

The feeding sources of the farmers were also similar to those in other studies. Furthermore, different housing types were utilized in both summer and winter - majority of which were extensive methods, and iron sheets, wire and bricks were the most commonly used housing material. This emphasizes the difference between commercial farms and informal sector. While the commercial farms allocate large amounts of capital, the informal sector are forced to utilize materials they find or those that are cost effective and available to them.

The markets' distance was most commonly 0 to 20km away and both sexes were sold by the farmer. The pig keepers' limitation of adequate transport for the animals limits them to a market which is closest to them. Furthermore, nearly half of the farmers keep records and majority of the farmers use ear tags to identify their animals.

The constraints that were mostly common to farmers in this study were inadequate housing resources, high cost of feed, lack of funds, prevalence of disease and hygiene and cost thereof and stock theft. The constraints experienced by the smallholder farmers limit their production as well as prevent them from entering the commercial industry. Many of the respondents listed more than one constraint that they face in the informal sector which emphasizes how many of the challenges may influence the other and therefore may be difficult to overcome.

Commerical production data collected can not be recorded by the pig keepers as these farmers are not able to hold down a sustainable production due to many compounding factors. Unfortunately, production data in the informal sector will only be possible for smallholder farmers who are market-orientated and can maintain a consistent production level. It does leave a gap in research about the pig keepers in the informal sector that will require further research.

Recommendations

The results of this study indicate that small farms are able to have similar production levels to larger farms which suggests that management is a crucial factor in determining the success of a pig farm, which allows for insight on how to bridge the gap between the commercial and informal sector. By holding workshops and educational seminars to pig keepers and smallholder farmers about management practices, production levels will see an increase.

Unfortunately, certain aspects of production such as slaughtering practices and disease management are the most unanswered questions in a questionnaire given to pig keepers and smallholder farmers. Disease management is crucial for maintaining healthy animals and healthy consumers if selling to the market or if the animals are used for home consumption. Slaughtering practices as well can influence the health of the consumers as knowledge on checking the meat for disease correctly can prevent transmission onto humans. From the discussion groups of this study, many of the farmers wanted more consistent information seminars where they can be educated on various topics. Thus a future study wishing to learn more about the disease management and slaughtering practices can include a workshop day on basic and affordable disease prevention and ways to check the meat for infection. From this study’s results the farmers’ will be very interested in attending.

Many of the constraints listed by the farmers of this study can be found in other sources of literature however only a few suggest possible solutions to them. Any future study should not only gather information about where knowledge is lacking but also provide ways to improve the farmers’ knowledge.

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Addendum

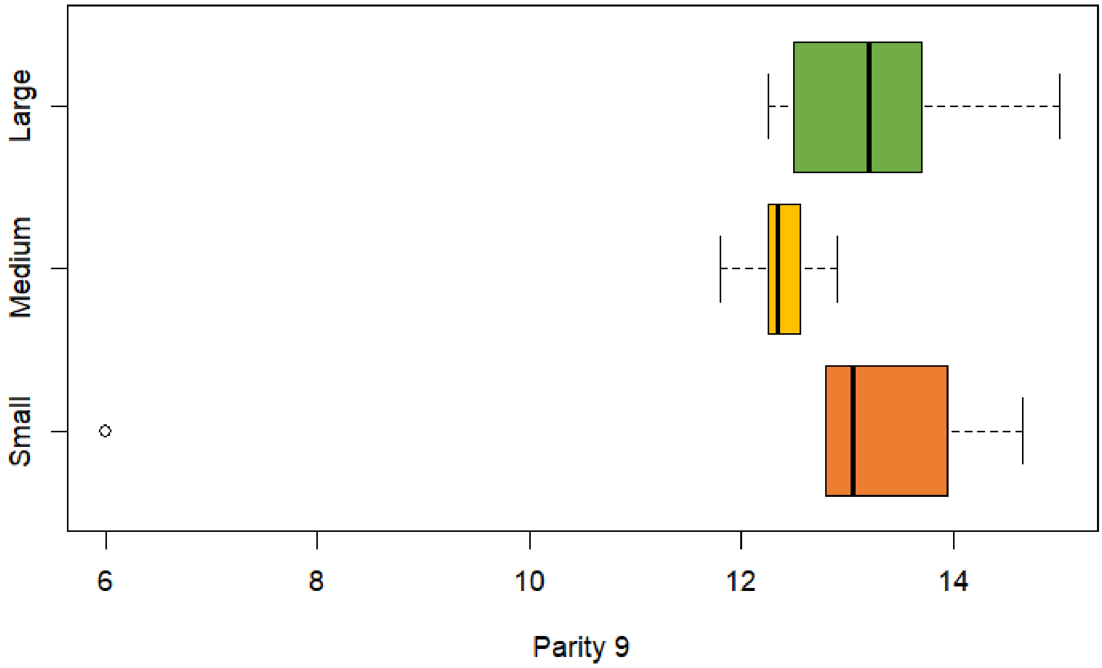
A. Descriptive statistics for NBA per parity.

Parities	Min	Max	Median (IQR)	Mean (SD)
Parity 1				
Small	6.8	11.45	9.9 (1)	9.77 (1.79)
Medium	10.1	12.75	11.05 (1.2)	11.38 (1.05)
Large	11.15	12.75	11.25 (1.45)	11.8 (0.82)
Parity 2				
small	10.1	13.2	11.85 (1.15)	11.56 (1.19)
medium	10.5	13.25	11.45 (1)	11.54 (1.08)
Large	12	13.45	12.4 (0.75)	12.58 (0.59)
Parity 3				
Small	10.5	13.55	11.9 (0.6)	11.99 (1.1)
Medium	11.05	13.25	11.1 (0.6)	11.64 (0.94)
Large	11.85	13.5	12.35 (1.05)	12.57 (0.7)
Parity 4				
Small	11	13.95	12.5 (0.9)	12.49 (1.09)
Medium	11	12.8	11.9 (0.25)	11.87 (0.64)
Large	12.5	13.75	12.8 (0.2)	12.91 (0.49)
Parity 5				
Small	12	14.15	13.05 (0.75)	12.93 (0.83)
Medium	11.75	13.25	11.95 (0.9)	12.31 (0.66)
Large	12.85	14	13.1 (0.25)	13.2 (0.47)
Parity 6				
Small	11.95	14.3	13.45 (1.25)	13.21 (0.95)
Medium	11.85	12.6	12.25 (0.3)	12.18 (0.29)
Large	12.5	14.05	13.2 (0.75)	13.14 (0.63)
Parity 7				
Small	12.1	14.1	13 (1.25)	13.11 (0.84)
Medium	12.1	12.95	12.45 (0.55)	12.55 (0.37)
Large	12.95	13.65	13.35 (0.4)	13.27 (0.29)
Parity 8				
Small	12.8	14	13.5 (1.1)	13.4 (0.58)
Medium	12.35	13.05	12.55 (0.5)	12.63 (0.31)
Large	12.7	13.85	13.5 (0.7)	13.27 (0.5)
Parity 9				
Small	6	14.65	13.05 (1.15)	12.09 (3.48)
Medium	11.8	12.9	12.35 (0.3)	12.37 (0.4)
Large	12.25	15	13.2 (1.2)	13.33 (1.1)

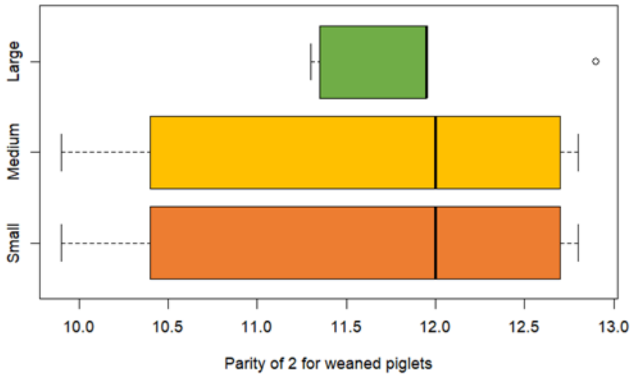
B. Descriptive statistics for NPW per parity.

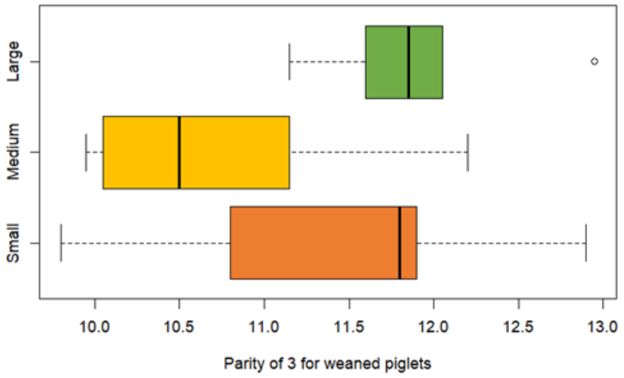
Parities	Min	Max	Median (IQR)	Mean (SD)
Parity 1				
Small	8	12.6	11.9 (3.8)	10.58 (2.24)
Medium	6.6	9.3	7.7 (1.15)	7.87 (1.04)
Large	8.95	11.05	9.95 (1.9)	9.97 (1)
Parity 2				
Small	9.9	12.8	12 (2.3)	11.56 (1.34)
Medium	9.9	12.8	12 (2.3)	11.56 (1.34)
Large	11.3	12.9	11.95 (0.6)	11.89 (0.65)
Parity 3				
Small	9.8	12.9	11.8 (1.1)	11.44 (1.18)
Medium	9.95	12.2	10.5 (1.1)	10.77 (0.93)
Large	11.15	12.95	11.85 (0.45)	11.92 (0.67)
Parity 4				
Small	11.4	13.5	12.2 (0.3)	12.24 (0.78)
Medium	10.5	12.2	10.85 (0.75)	11.2 (0.69)
Large	11.3	12.7	11.7 (0.55)	11.89 (0.55)
Parity 5				
Small	10.8	13	11.9 (0.9)	11.96 (0.84)
Medium	10.7	12.1	11.05 (0.9)	11.25 (0.61)
Large	11.3	12.55	11.75 (1.1)	11.88 (0.59)
Parity 6				
Small	10.9	12.9	12.2 (1.5)	11.86 (0.91)
Medium	11.15	14.7	12.15 (1.7)	12.44 (1.46)
Large	11.15	12.4	11.4 (0.7)	11.65 (0.53)
Parity 7				
Small	11.1	12.8	12.5 (1.1)	12.1 (0.75)
Medium	10.35	11.25	11.1 (0.55)	10.89 (0.39)
Large	11.35	12.05	11.7 (0.4)	11.66 (0.29)
Parity 8				
Small	11.3	12.7	12.5 (0.8)	12.18 (0.61)
Medium	10.15	11.65	11.1 (0.75)	11.07 (0.62)
Large	11.15	11.95	11.85 (0.5)	11.63 (0.36)
Parity 9				
Small	10.5	10.9	10.8 (0.3)	10.74 (0.18)
Medium	9	12.1	10.1 (2.05)	10.65 (1.37)
Large	10.4	11.25	10.9 (0.4)	10.87 (0.33)

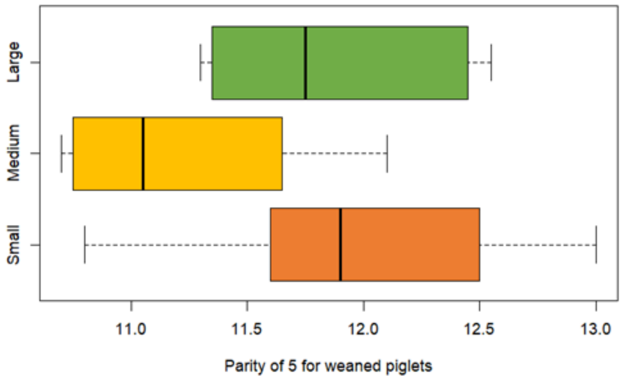
C. Variation for number born alive parity 9.

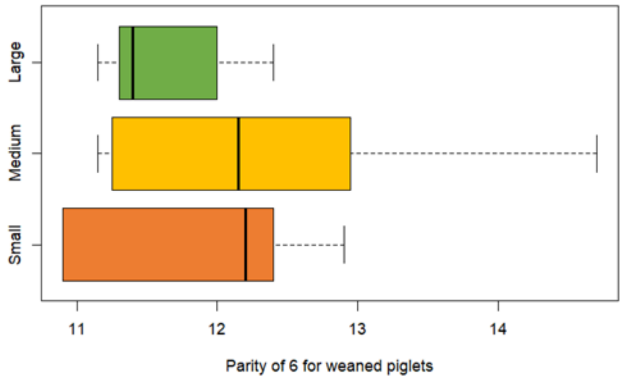


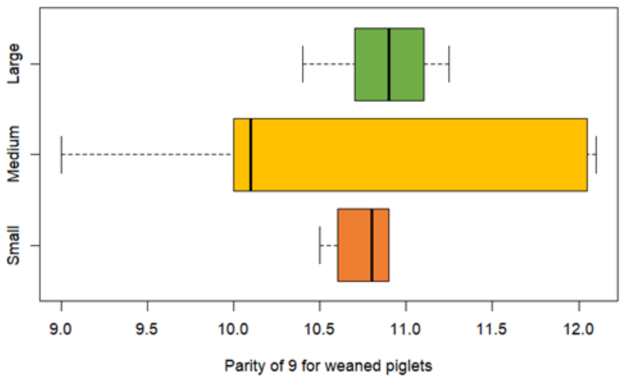
D. Variation for number of piglets weaned parities two, three, five, six and nine.











E. Questionnaire

Go rua dikolobe mo porofenseng ya Bokone Bophirima

Thuo ya dikolobe mo porofenseng ya Bokone Bophirima e thusa thata mo go sireletseng dijo le go dira gore balemi ba ba humanegileng ba nne le madi a lotseno. Gore go nne le mekgwa e e mosola e e ka dirisiwang go tokafatsa thuo, go sireletsega ga dijo, boleng jwa dijo le boitekanelo jwa dikolobe tseno; go botlhokwa go tlhaloganya gore ke didirisiwa dife tse di leng gone, tsela ya go tshwara dikolobe tseno mmogo le kwa go nang le ditshono tsa go tokafatsa boemo jwa tsone. Seno ke ka gonne batho ba ba ruileng diphologolo tseno, ba ba di tlhokomelang le go di dirisa, ba tla tlhomamisa go atlega ga patlisiso eno. Ka jalo, boikaelelo jwa potsolotso eno ke go tlhaloganya ditsela tse balemirui ba ba leng mo mafelong a mannye ba di dirisang go tlhagisa leruo la dikolobe.

Pig production in the Northwest province has great potential for food security and income generation to the poor resource farmers. In order to effectively strategize how to improve the production, food safety, food quality and welfare of such pigs; it is important to understand which resources are available, the general management of such pigs as well as where opportunity lies to improve their condition. This is because the people who own, look after and utilize these animals will determine the success of this study. Therefore, the aim of this survey is to understand pig production systems in a smallholder area.

1. TSHEDIMOSETSO YA BAAGI (DEMOGRAPHIC INFORMATION)

a) Motsayakarolo 1 (Respondent 1) ____________________

b) Aterese (Address) ________________________

c) Motse (Village) __________________________

d) Kgaolo (region) __________________________

e) Lefelo (Location) _________________________

f) Kgaolo (district) __________________________

2. MALOKO A LELAPA (Household structure)

2.1) Mong wa lefatshe (land ownership)

a) ke la gagwe (own) b) o hirile (lease) c) e nngwe (Tlhalosa) (other) (specifiy) ______________

2.2) Tlhogo ya lelapa (head of household)

a) Monna (male) b) Mosadi (female)

2.3) Diphologolo ke tsa ga mang? (Who owns the animals?)

a) rremogolo kgotsa koko (grandparent) b) motsadi (parent) c) ngwana (child) d) setšhaba (community) e) e nngwe (other)

2.4 Dingwaga tsa motho yo diphologolo e leng tsa gagwe (The age of the person who owns the animals)

a) ≤ 18 b) 18-30 c) 30-45 d) 45-60 e) >61

2.5 Mong wa diphologolo o tsene sekolo go fitlha kae (level of education of the owner)

a) Sekolo sa Poraemari (primary) b) Sekolo sa Bogareng (secondary) c) Sekolo se Segolwane (tertiary) d) Ga a tsena sekolo (none)

2.6) A thuo ya dikolobe ke yone tiro e kgolo? (is pigs a major activity?)

a) Ee (yes) b) Nnyaa (no)

2.7) Tsweetswee tlatsa lebokoso le le fa tlase (please fill in the table below)

	Monna (male)	Mosadi (female)	Bana (children)
Palo ya batho ba ba nnang mo ntlong (Number of people living in the household)			
Palo ya batho ba ba tlhokometsweng (Number of beneficiaries)			

2.8) Kwa lotseno lo tswang teng (Tsweetswee tshwaya mo go tshwanetseng mme o di lekanye go ya ka botlhokwa jwa tsone) (Source of income) (please tick where applicable)

Tiro	Tshwaya
Dikolobe (pigs)	
Dijalo (crops)	
Dilo tse di tswang mo leruong (livestock products)	
Tuelo (salary/ Wages)	
Tse dingwe (other)	

2.9) Diruiwa (Kwala palogotlhe ya mofuta mongwe le mongwe wa diphologolo tse di ruilweng mme o di lekanye go ya ka botlhokwa jwa tsone) (livestock kept)

Diruiwa (livestock)	Palo (number)
Dikolobe (pigs)	
Dipudi (goat)	
Dinku (sheep)	
Dikoko* (chicken)	
Dikgomo (cattle)	
Ditonki (donkey)	
Tse dingwe (other)	

*dinonyane tse dikgolo fela (adult birds only)

2.10 Kwa dikolobe tse di ruilweng di tswang teng (origin of pigs kept)

a) di rekilwe (bought) b) ke boswa (inherited) c) Ke dimpho (gifts) d) di bonwe go tswa mo thulaganyong nngwe ya goromente (acquired through a government scheme) e) go refosanwe (exchanged) f) e nngwe (other)

2.11) Maloko a lelapa a a ikarabelang ka go tlhokomela dikolobe (*Tshwaya mo go tlhokegang*) (Members of the household responsible for the pig activities)

Tiro (activity)	Monna yo o godileng (male adult)	Mosadi yo o godileng (female adult)	Bana (<15) (children)	Batho ba ba hirilweng (hired labour)	Batho ba mo setšhabeng (community)
Go di fepa (feeding)					
Ditshwetso tsa go atisa leruo (breeding decisions)					
Go di tlhaba (slaughtering)					
Go rekisa (selling)					
Go reka (purchasing)					
Boitekanelo jwa diphologolo (animal health)					
Tse dingwe (other)					

3. <u>PALO YA MOTLHAPE (herd structure)</u>

3.1) Go na le dikolobe di le kae? (what is the number of sows?)

a) 0-20 b) 21-50 c)51-100 d)101-200 e) >200

3.2) A o na le kolobe ya naga? Fa go le jalo, ke tse kae? (Do you have a boar? Is yes, how many?)

a) Ee (yes) b) nnyaa (no)

*Palo ya dikolobe tsa naga (number of boars) ________________

3.3) A o dira gore di duse ka tsela ya tlholego kgotsa ya maitirelo? (do you do natural mating or AI?)

a) Go dira gore di duse ka tsela ya tlholego (natural mating) b) Go dira gore di duse ka tsela ya maitirelo (AI)

3.4) A go ruilwe dikolobe le diphologolo tse dingwe? (Do the pigs run with other animals?)

a) Ee (yes) b) nnyaa (no)

3.5) **Palo ya dikolobe tse di ruilweng; dira sekele mo nomorong e e bontshang dikolobe tse di leng teng ka nako eo (Herd structure of pigs kept; circle where applicable number kept at that time)**

Dikolojwane (piglets) (dibeke tse ≤ 6) (less than 6 weks)	Tse di sa tswang go kgwisiwa letsele (weaners) (dibeke tse 6-10) (between 6-10 weeks)	Tsa bogolo jwa (growers) (dibeke tse 10-16) (between 10-16 weeks)	Tsa bogolo jwa (growers) (dikgwedi tse 5-12) (between 5-12 months)	Tse go ka dirwang beikhone ka tsone/Tse di godileng (baconers/finishers) (dibeke tse 17-22/24) (between 17-22/24 weeks)
a) ≤ 10	a) ≤ 10	a) ≤ 10	a) ≤ 10	a) ≤ 10
b) 10 – 20	b) 10 – 20	b) 10 – 20	b) 10 – 20	b) 10 – 20
c) 21 – 40	c) 21 – 40	c) 21 – 40	c) 21 – 40	c) 21 – 40
d) 41 -50	d) 41 -50	d) 41 -50	d) 41 -50	d) 41 -50
e) >50	e) >50	e) >50	e) >50	e) >50

4. GO FEPA LE GO NOSETSA (feeding and watering)

4.1) Kwa dijo di tswang teng. (Tshwaya) (source of feed, tick)

A o reka dijo? (do you buy feed?)	
Dijo tse di tswang mo ntlong tse di yang go latlhiwa (food waste from house)	
Masaledi a merogo (vegetable leftovers)	
Dijalo tsa bogologolo (use of old crops)	
Metswako e o itirelang yona (mixing your own)	
Tse dingwe (other)	

4.2) Kwa metsi a tswang teng (Tshwaya) (Source of water, tick)

	Mariga (Summer)	Selemo (Winter)
Sediba (borehole)		
Noka (river)		
Mogobe (pond)		
Metsi a pula (rainwater)		
Metsi a thepe (tap water)		
Tse dingwe (other)		

4.3) Makgetlo a go nosediwang ka one (Tshwaya) (frequency of water given)

	Mariga (Summer)	Selemo (winter)
Gantsi ka mo go ka kgonegang (adlib)		
Gangwe ka letsatsi (once a day)		
Gabedi ka letsatsi (twice a day)		
Go tlodiswa letsatsi (every other day)		
Morago ga malatsi a le 3 (once every 3 days)		
Tse dingwe (other)		

4.4) A o di naya metsi ka mogopo kgotsa ka thoba? (do you give water with a trough or nipple?)

a) mogopo (trough) b) thoba (nipple)

5. <u>LEFELO LE DI NNANG MO GO LONE (housing type)</u>

5.1) A o na le legora? (do you have a fence)

a) ee (yes) b) nnyaa (no)

5.2) A ntlo eo e tshwanela go nna dikolobe? (is the house pig proof?)

a) ee (yes) b) nnyaa (no)

5.3) A mofuta mongwe le mongwe wa dikolobe o na le ntlo ya one? (do you have different houses for different production stages?)

a) ee (yes) b) nnyaa (no)

5.4) Mofuta wa ntlo (Tshwaya) (method of housing, tick)

Mofuta (method)	Mariga (Summer)	Selemo (Winter)
Masaka (kraals)		
Setale/ntlwana (stalls, sheds)		
Jarata (yard)		
Ga go na sepe (none)		

E nngwe (other) __________		

5.5) Dilo tse go agilweng ka tsone le mefuta ya boalo le dipota (Tshwaya) (materials used and type of floors and walls, tick)

Go ruletswe (roofed)	
Lebota le le nonofileng (solid wall)	
Boalo jwa konkereiti (concrete floor)	
Boalo jwa logong (wooden floor)	
Boalo jwa samente (earth floor)	
Go dirisitswe diterata (wire used)	
Go dirisitswe seretse (mud used)	
Go dirisitswe ditena (bricks used)	
Logong lo lo sa fetolwang (untreated wood))	
Logong lo lo fetotsweng (Treated wood)	
Disenke (iron sheets)	
Tse dingwe (other)	

6. PAPATSO LE GO BOLAYA (marketing and culling)

6.1 A o bolaya dikolobe? (do you cull?)

a) Ee (yes) b) Nnyaa (no)

Mabaka (reasons)	E Tona (male)	E Tshadi (female)
E kotsi (temperament)		
Malwetsi (diseases)		
Botsofe (old age)		
Bogole jo e tshotsweng ka jone (congenital deformities)		
Go dira mo go bokoa (poor performance)		
Bogolo ba mmele (body size)		
Popego ya mmele (body conformation)		
Ga e tsale ka mo go lekaneng (small litters)		
E tsala palo e e kwa tlase thata (low number of litters)		
Boleng jo bo kwa tlase jwa peo ya thobalano (poor semen quality)		
Ga e kgone go tlhokomela bana ba yone (poor mothering ability)		
Ga di gole sentle (poor growth)		
Go tlhoka keletso ya thobalano (low libido)		
E nngwe (other)		

6.2 A o rekisa dikolobe tsa gago? (do you sell your pigs?)

a) Ee (yes) b) Nnyaa (no)

6.3) O rekisa gakae? (how often do you sell?)

a) letsatsi le letsatsi (daily) b) beke le beke (weekly) c) kgwedi le kgwedi (monthly) d) fa di le teng (when available) e) fa o tlhoka madi (when you need cash) f) ka malatsi a boikhutso (holidays) g) fa go na le meletlo (ceremonies) h) fa go na le leuba (droughts) i) fa dijo di tlhaela (shortage of food) j) tse dingwe (other)

6.4) O rekisa kae? (where do you sell?)

a) Barekisi (traders) b) Bareki (consumers) c) Balemi (farmers) e) difantisi (auctions) e) botlhabelong (abbatoris) f) tse dingwe (other)

6.5) Sekgala go tswa mo dikolobe di nnang go ya borekisetsong (distance from production point to market)

a) 0-20km b) 21-50km c) 50 -100km d)>100km

6.6) Bong jwa diphologolo tse di rekisiwang (sex of animals sold)

a) tse ditona (male) b) tsa tshadi (female) c) fa di kopane (mixed)

6.7) Dingwaga tsa diphologolo tse di rekisiwang (age of animals sold)

a) dikgwedi tse (months) ≤ 6 b) dikgwedi tse (months) 7-12 c) dikgwedi tse (months) 12-18 d) dikgwedi tse (months) 18-24 e) dikgwedi tse (months) 24-36 f) dikgwedi tse (months) >36

<u>7. MEKGWA YA GO DI TLHABA (slaughtering practices)</u>

7.1) Diphologolo di tlhabelwa kae? (where are the animals slaughtered?)

a) botlhabelong (abbatoir) b) di tlhabelwa mo sekgweng/kwa gae (bush slaughtering/home)

7.2) A o di tlhaba gore lo je? (do you slaughter for your own consumption?)

a) Ee (yes) b) Nnyaa (no)

7.3) Ke dikolobe tse kae tse o di tlhabelang gore lo je mo lapeng? (how many pigs do you slaughter for home consumption?)

a) 0-2 b) 2-5 c)5-10 d) >10

7.4) O tlhabela lapa la gago gakae? (how often do you slaughter for own consumption?)

a) beke le beke (weekly) b) kgwedi le kgwedi (monthly) c) fa go tlhokega (when needed)

<u>8. GO ATISA (breeding)</u>

8.1) Motswedi wa go atisa dikolobe ya naga (source of breeding boar)

a) Adimilwe (borrowed) b) hirisitswe (hired) c) rekilwe (bought) d) motlhape wa gago (own herd) e) lefelo la setshaba la dikolobe tsa naga (community area boar) f) e nngwe (other)

8.2) Fa e le gore di rekilwe, di rekilwe kae? (if they were bought, where from?)

a) Polasi ya go atisa (stud breeder) b) molemirui wa kgwebo (commercial farmer) c) molemirui wa mo tikologong (local farmer) d) e nngwe (Other)

8.3) Mofuta wa dikolobe (leina la mofuta oo, fa o le itse) (type of pig, breed if known)

____

8.4) O boloka dikolobe tsa naga nako e kae gore o di atise? (how long do you keep the boar for breeding?)

a) dingwaga tse (years) 1-2 b) dingwaga tse (years) 2-4 c) dingwaga tse (years) ≥5

8.5) Boleng jwa mofuta wa dikolobe tse di ruilweng (bokgoni jwa molemirui) di lekanye go ya ka (Bokoa, magareng & sentle) (Quality of trait on the breed kept (farmer's perception) rate them)

Boleng (trait)	E tona (male)			E tshadi (female)		
	Bokoa (poor)	Magareng (average)	Sentle (good)	Bokoa (poor)	Magareng (average)	Sentle (good)
Tsela e di golang ka yone (growth rate)						
Bogolo jwa mmele (body size)						
Popego ya mmele (body conformation/size)						
Mmala (colour)						
Nama (meat)						
Mashi (milk)						
Boima jwa dikolojwane tse di sa tswang go tsholwa (high litter size)						
Palo e e kwa godimo ya dikolojwane tse di						

sa tswang go tsholwa (high number of litters)						
Go itshokela malwetse (disease tolerant)						
Go itshokela leuba (drought tolerant)						
Go itshokela mogote (heat tolerant)						
Mekgwa/Boitsholo (temperament)						
Popego ya mmele (body shape)						
Fertility						
Tse dingwe (other)						

9. GO BOLOKIWA GA DIREKOTO

9.1) A o boloka direkoto tsa thuo ya dikolobe? (do you keep records for your farm?)

a) ee (yes) b) nnyaa (no)

9.1.2) Fa go le jalo o rekota jang? Tsweetswee tshwaya mo lebokosong le le fa tlase (if yes what do you record? Please tick in the table below

Mekgwa e e rekotilweng (traits recorded)	**Tshwaya (tick)**
Tlhwatlhwa ya go di tlhagisa (cost of production)	
Lotseno lo lo bonwang fa di tlhagiswa (income from production)	
Boima (weight)	
Palo ya dikolojwane tse di tsetsweng (number of piglets born)	
Ke gakae/fa kolobe e tsala (how often/when a sow gives birth)	
Tse di swang (mortality)	
Palo ya dikolojwane tse di kgwisitsweng (number of piglets weaned)	
Tse dingwe (other)	

9.1.3) Fa go se jalo, goreng? (if no, why?)

a) tlhwatlhwa (cost) b) e nngwe (other)

9.2.1) A o tshwaya dikolobe tsa gago? (do you identify your pigs?)

a) ee (yes) b) nnyaa (no)

9.2.2) fa go se jalo, goreng? (if no, why?)

a) madi (cost) b) ga go kgonege (not accessible) c) di ka rekwa fela ka bontsi (can only be bought in bulk) d) tse dingwe (other)

9.2.3) O dirisa eng? (what do you use?)

a) ditatoo (tattoos) b) letshwao mo tsebeng (eartag) c) ka bobedi (both) d) sepe (none)

10. MATHATA A MAGOLO (Major constraints)

Kwala mathata a go lebanwang le one go ya ka tsela e a tlhagang ka yone (list the constraints on your farm):

____

____

____

____

11. DILO TSE GO KA KGONEGANG GORE GO TOKAFADIWE MO GO TSONE (Areas of possible improvement)

Kwala dilo tse barui ba dikolobe ba akanyang gore go tlhokega go tokafadiwa mo go tsone (List the areas that you feel could be improved on your farm)

____

____

____

____