FREE-ROAMING PIG PRODUCTION IN THE PERI-URBAN AREAS OF GERT SIBANDE DISTRICT IN MPUMALANGA PROVINCE, SOUTH AFRICA: HUSBANDRY PRACTICES, NUTRITION, AND PARASITE BURDEN.

by

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Submitted in accordance with the requirements for

the degree of

DOCTOR OF PHILOSOPHY

IN AGRICULTURE

&

at the

COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

UNIVERSITY OF SOUTH AFRICA

SOUTH AFRICA

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FEBRUARY 2025

DEDICATION

I dedicate this work to my mother, son, and daughter, who have consistently supported me with motivation, prayers, and unconditional love. Words alone cannot express how grateful I am for their unwavering affection and assistance.

I also dedicate this work to all women who have experienced life's trials, especially the hardworking single mothers who are raising their children on their own. Always be driven and ambitious, focus on your goals, and seek the Lord's direction as you strive to improve yourself and overcome your current situation. Combining hard work and determination can lead to outstanding accomplishments.

DECLARATION

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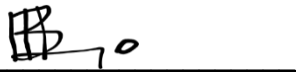
I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the thesis to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at UNISA for another qualification or at any other higher education institution.



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28/02/2025
DATE

ACKNOWLEDGEMENTS

Proverbs 2:6 "For the LORD giveth wisdom: out of His mouth cometh knowledge and understanding." I express my profound appreciation to the Almighty God (Jesus Christ of Nazareth); despite encountering setbacks and challenges, I found motivation in His Word to stay focused.

I would like to express my gratitude to my promoters, Prof. J.W. Oguttu, Prof. F.O. Fasina, and Prof. C.A. Mbajiorgu, for their invaluable guidance and unwavering support throughout this project. The experience of collaborating with such proficient individuals was exceptional. They continuously helped me understand my potential and the simplicity of complex issues. My baby sister, Dr Rabelani Munyai, and Ms. Sphiwe Molefi played a crucial role in my accomplishment by consistently providing me with encouragement, especially during times when I felt incapable of continuing. You embody ambition and determination.

I would like to express my heartfelt appreciation to the Mpumalanga Department of Agriculture (DARDLEA) and University of South Africa (UNISA) Master's & Doctoral bursary for funding my research. Additionally, I would like to extend my appreciation to the South African Veterinary Epidemiology and Preventive Medicine (SASVEPM) for funding my participation in the 19th and 20th annual Congress and allowing me to share some of the research findings.

I would like to express my gratitude to the Gert Sibande District Municipality (GSDM) for granting me permission to conduct this study. I am also thankful to all the peri-urban pig farmers in the study areas for their willingness to enable me to utilise their pigs in this study, and for the valuable information, they shared that made this study possible.

I am grateful to the members of the Mpumalanga Agricultural Research Committee (MARC), my manager Mr ML Scheltens, the personnel at the Nooitgedacht Research Farm (Animal Research colleagues), the Mpumalanga Provincial Veterinary Laboratory (MPVL), and the Technology Transfer section for their feedback, support,

and collaborative partnership. I extend my gratitude to Mr. Velly Absalom Mhlanga and Mr. Stewart Sibeko for their invaluable assistance in sample gathering. In addition, the agricultural advisors and animal health professionals in all seven municipalities of the Gert Sibande District Municipality granted access to the participants in the research areas. I am also grateful to everyone who helped this study succeed.

I am grateful to Dr. N.P. Mafenya and Prof. F.O. Fasina for motivating me to pursue a doctorate degree after completing my Master of Science Degree. I am thrilled that I followed your advice and achieved this milestone. Throughout my academic journey, there were instances in which I believed that persevering would be an impassable challenge. However, my grandmother, Mrs. Regina Makungo, and my mother, Ms. Tshifhiwa Hilda Makungo, persistently served as sources of motivation, encouragement, and inspiration. "My two children, Watshilidzi and Ankonisaho Munzhelele, are the most precious gifts that life has bestowed upon me." I aspire for them to grow up and acquire knowledge, thereby surpassing my own level of education. I am grateful for the unwavering support of my family and friends. My late father, Vho Mphumudzeni Maphutha, I wish you were still alive to witness this, but God had a better plan for you. May your soul continue to rest in peace.

To God be glory in Jesus' name…

LIST OF ABBREVIATIONS

ADF	Acid Detergent Fibre
AHAW	Scientific Panel on Animal Health and Welfare
ANOVA	Analysis of Variance
ASF	African swine fever
ASH	Total Inorganic Matter
BCS	Body Condition Score
Ca	Calcium
CAES	College of Agriculture and Environmental Science
CALM	Chief Albert Luthuli Municipality
CF	Crude Fibre
CP	Crude Protein
CSF	Classical Swine Fever
DAFF	Department of Agriculture, Fisheries and Forestry (National)
DALRRD	Department of Agriculture, Land Reform and Rural Development (National)
DARDLEA	Department of Agriculture, Rural Development, Land Administration and Environmental Science
DF	Degree of freedom
DM	Dry Matter
EFSA	European Food Safety Authority
EPG	Eggs per Gram
ETC	Et Cetera
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FEC	Faecal Egg Counts
FMD	Foot-and-Mouth Disease
FRP	Free Roaming Pig
FS	Free State Province
G	Gram
GDP	Gross Domestic Product

GIT	Gastrointestinal Tract
GP	Gauteng Province
GSDM	Gert Sibande District Municipality
HS	Household Swill
Km^2	Square Kilometre
KZN	KwaZulu Natal Province
M	Moisture
MANOVA	Multivariate Analysis of Variance
mm	Millimetre
MP	Mpumalanga Province
MPVL	Mpumalanga Provincial Veterinary Laboratory
M&D	Masters and Doctoral
NA	Not Applicable
Na	Sodium
NDP	National Development Plan
P	Phosphorus
P	P-value
pH	Potential of hydrogen
PUA	Peri-Urban Areas
r	Correlation Coefficient
R	Rand
RCCE	Risk Communication and Community Engagement
RS	Restaurant Swill
SA	South Africa
SASVEPM	South African Congress for Veterinary Epidemiology and Preventive Medicine
SD	Standard Deviation
SOP	Standard Operating Procedure
SPSS	Statistical Package for the Social Sciences
SS	School Swill
TB	Tuberculosis
UNICEF	United Nations International Children's Emergency Fund
UNISA	University of South Africa
WS	Wholesaler Swill

X^2	Chi-square
^oC	Degree Celsius
=	Equal sign
β	Beta
α	Alpha

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PUBLICATION ARISING FROM THIS THESIS

LIST OF PUBLICATION IN PEER REVIEWED JOURNALS:

1. Munzhelele, P., Sibeko, N. P. S., Oguttu, J. W., Mbajiorgu, C. A., & Fasina, F. O. (2024). Parasites burden in peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga Province, South Africa. **Journal of the South African Veterinary Association**, 95(1), 55-66. https://doi.org/10.36303/JSAVA.601.

2. Makungo, P., Fasina, F. O., Mbajiorgu, C. A., & Oguttu, J. W. (2025). Free-roaming pig husbandry practices in a peri-urban setting in Mpumalanga, South Africa. ***Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 126(2) (2025):171–179.*** 10.17170/kobra-kobra-2025081111368

3. Makungo, P., Fasina, F. O., Mbajiorgu, C. A., & Oguttu, J. W. (2025). Nutrient composition of swill fed to peri-urban free-roaming pigs in Gert Sibande, South Africa. ***South African Journal of Animal Science (SAJAS), Vol. 55 No. 9 (2025)*** *https://doi.org/10.17159/sajas.v55i9.01*.

SCIENTIFIC PRESENTATIONS MADE AT PEER REVIEWED EVENTS:

1. **19th Annual South African Society for Veterinary Epidemiology and Preventive Medicine (SASVEPM)** at East London, Eastern Cape province, **24 – 26 August 2022**. Topic: A preliminary report: Prevalence of ecto- and endoparasites in the peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga province, South Africa. https://sasvepm.org/wp-content/uploads/SASVEPM-2022-proceedings.pdf, Page 51.

2. **12th Research and innovation day**, **University of South Africa College of Agriculture and Environmental Sciences (CAES).** Florida, Johannesburg, Gauteng province, South Africa. **17 May 2023**. Topic: Peri-urban free roaming pigs in Gert Sibande District Municipality, Mpumalanga province, South Africa.

3. **20th Annual South African Society for Veterinary Epidemiology and Preventive Medicine (SASVEPM).** Gaborone, Botswana. **23 – 25 August 2023**.

Topic: Parasites burden in peri-urban free-roaming pigs in Gert Sibande District Municipality of Mpumalanga province, South Africa.

4. **21st Annual South African Society for Veterinary Epidemiology and Preventive Medicine (SASVEPM).** Cape Town, Western Cape province. **21 – 23 August 2024**. Topic: Husbandry practices among peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga province, South Africa.

5. **22nd Annual South African Society for Veterinary Epidemiology and Preventive Medicine (SASVEPM).** White River, Mpumalanga province. **20 – 22 August 2025**. Topic: The potential and challenges of feeding swill to pigs in the peri-urban areas of Gert Sibande District Municipality, Mpumalanga, South Africa. https://sasvepm.org/22nd-annual-sasvepm-congress-2025.

EXECUTIVE ABSTRACT

Shortage of agricultural land in South Africa has led to an increase in the popularity of free-roaming pig (FRP) farming in peri-urban areas (PUAs). This study explored the husbandry practices, production constraints, and prevalence of ecto- and endoparasites among peri-urban FRPs. The study also quantified and determined the nutritional profile of commonly used swill in the PUAs of Gert Sibande District Municipality (GSDM). Snowball sampling was used to recruit 124 pig producers. A total of 283 pigs were selected using stratified sampling to determine the presence of ecto- and endoparasites. The following swill samples (n=14) were collected using purposeful sampling: household swill (HS), school swill (SS), restaurant swill (RS), and wholesaler swill (WS). Data were analysed using Stata 15.0 and SPSS V28.0 statistical software packages. Statistical significance was set at $\alpha = 0.05$ for all analyses. Most (90%) of the GSDM FRPs had parasites, including *Haematopinus suis, Sarcoptes scabiei, Ascaris suum, Fasciola hepatica, Trichuris suis, Strongylids, Coccidia spp., Moniezia expansa,* and *Siphonaptera spp*. Most farmers (93.5%) engaged in peri-urban FRP farming without local authority approval, and 72.6% were unregistered for animal identification. Most of the farmers (94.35%) did not implement disinfection measures, and 87.1% were unaware of transboundary animal and zoonotic diseases. Swill analysis showed that HS and SS had a higher moisture content (80.14% and 80.27%, respectively) as compared to RS and WS (54.36% and 56.63%, respectively). The HS and SS had a low DM content (19.86±8.21 g/kg DM and 19.73±6.94 g/kg, respectively) compared to RS and WS (45.65±27.57 g/kg and 43.37±25.45 g/kg, respectively). All FRP producers fed pigs with swill, including untreated swill (92.7%). Few FRP farmers fed home-mixed feeds (26.6%), alternative feeds (25%), and conventional feeds (12.1%). To enhance biosecurity, study findings support the dismantling of the existing peri-urban FRP system and transforming it into a controlled, restricted system. The farmers should be encouraged to establish a cooperative to facilitate the translation and management of the FRP. Around 90% of GSDM FRPs had one or more of nine parasites. The nutritional value of swill as feed for piglets and weaners in the FRP production system can be improved by combining the nutritious WS with the less nutritious HS. Furthermore, combining SS and RS can also achieve an ideal diet for growing pigs.

Keywords: gastro-intestinal parasites, ecto-parasites, zoonosis, pig production systems, food security, nutrient composition, swill feeding, pig husbandry, proximate analysis, biosecurity

ṰHALUTSHEDZO YA VHULANGULI

U shayea ha mavu a u lima Afurika Tshipembe zwo ita uri hu vhe na u engedzea ha u fuwa nguluvhe dzo vhofholowa (FRP) kha vhupo ha tsini na ḓorobo (PUAs). Ino pfunzo yo lavhelesa nḓila dza u alusa, mathada a u ita tshibveledzwa, na u vhonala ha zwikhokhonono zwa nnda na zwa thumbuni kha FRPs kha PUA. Pfunzo yeneyi yo dovha ya sedza tshivhalo tsha zwiḽiwa zwa masalela zwi shumiswaho nga vhafuwi vha FRP kha Masipala wa Gert Sibande District Municipality (GSDM). Snowball sempulingi yo shumisiwa kha u nanga vhafuwi vha nguluvhe vha 124. Dzinguluvhe (n=283) dzo nangiwa hu tshi khou shumisiwa sitiratifaidi sempulingi u vhona arali dzi na zwikhokhonono zwa thumbuni na zwa nnda. Dzisempulingi dza zwiḽiwa zwo masalela (n=14), zwa u bva kha masalela a mudini (HS), masalela a tshikoloni (SS), masalela a resiturente (RS), na masalela a murengisi wa zwithu zwinzhi (WS) zwo khethekanyiwa nga nḓila ya u dzudzanywaho. Data yo senguluswa hu tshi shumiswa Stata 15.0 na SPSS V28.0 tshivhalo tsha muhwalo tsha phurogireme. Vhuimo ha ndeme ya tshivhalo ho imisiwa kha α = 0.05. Vhunzhi ha (90%) ya FRPs dzo vha dzi na zwikhokhonono, zwi tshi katela *Haematopinus suis*, *Sarcoptes scabiei*, *Ascaris suum*, *Fasciola hepatica*, *Trichuris suis*, *Strongylids*, *Coccidia spp*., *Moniezia expansa*, na *Siphonaptera spp*. Vhafuwi vha FRP vhanzhi (93.5%) vho vha vho di dzhenisa kha vhufuwi ha tsini na dorobo hu si na thendelo ya vharangaphanḓa, nahone 72.6% a vho ngo ṅwalisa zwifuwo zwa vho kha ṱalula tshifuwo. Vhafuwi vhanzhi (94.35%) a vha ngo shumisa zwikhala zwa u tsireledza zwa mutakalo, nahone vho vha vha si na vhuṱanzi ha malwadze a u phambana ha shango na malwadze a pfukela (87.1%). HS na SS vho vha vha na maḓi manzhi (80.14% na 80.27%) u fhira RS na WS (54.36% na 56.63%). Nga tshenetsho tshifhinga, HS na SS vho vha vha na DM i tshee fhasi (19.86±8.21 g/kg DM na 19.73±6.94 g/kg) u fhira RS na WS (45.65±27.57 g/kg na 43.37±25.45 g/kg). Vhalimi vhoṱhe vho fha nguluvhe dzavho zwiḽiwa zwa masalela, nahone vhanzhi vho fha zwiḽiwa zwa masalela zwi si ngo tsireledzeaho (92.7%). Vhalimi vha si gathi (26.6%) vho fha zwiḽiwa zwa masalela a muṱani, 25% vha fha zwiḽiwa zwiṅwe, nahone 12.1% vha fha zwiḽiwa zwo ḓoweleaho. U khwinisa tsireledzo ya zwifuwo, mawaṅwa a ngudo a tikedza u fhaladzwa ha maitele a tsini na ḓorobo FRP ane avha hone na u shandukisa maitele avha a langwaho, o tsireledzwaho. Vhalimi vha fanela u ṱuṱuwedziwa vha thome tshumisano u shandukisa na u langa FRPs. Vhunzhi ha FRPs (90%) dzo vha dzi na nthihi kana zwinzhi zwa zwikhokhonono

zwo ṱaluswaho. Tshivhalo tsha mutakalo wa zwiḽiwa zwa masalela zwi shumiswa u fusha zwiguluzwana na dzine dza bva kha mme kha u bveledzisa maitele a FRP tshi nga khwaṱhisedzwa nga u tanganisa WS ine ya vha na mutakalo na HS une wavha fhasi. U ṱanganya SS na RS zwi nga shumiswa kha u wana zwo teaho mutakalo wa dzinguluvhe dzi aluwaho.

Maipfi a ndeme: zwikhokhonono zwa nga ngomu thumbuni, zwikhokhonono zwa nnda, malwadze a u pfukela, maitele a u alusa nguluvhe, tsireledzo ya zwiḽiwa, mutakalo wa zwiḽiwa, u fha zwiḽiwa zwa masalela, u alusa dzinguluvhe, u sedza nga u dzudzanya, tsireledzo ya zwithu zwi tshilaho.

UITVOERENDE OPSOMMING

’n Tekortkoming aan landbougrond in Suid-Afrika het gelei tot ’n toename in vrylopende varkboerdery in buitestedelike gebiede. Hierdie studie het die veeteelt-praktyke, produksie-beperkings en die voorkoms van ekto- en endoparasiete onder vrylopende varke in buitestedelike gebiede verken. Die studie het ook die voedingsprofiel van kombuisasfval (*swill*) bepaal wat algemeen gebruik word deur vrylopende varkboere in die buitestedelike gebiede van die Gert Sibande-distriksmunisipaliteit (GSDM). Sneeubalsteekproefneming is aangewend om 124 varkprodusente te werf. Varke (n=283) is gekies deur gestratifiseerde steekproefneming om die voorkoms van ekto- en endoparasiete te bepaal. Kombuisafvalmonsters (n=14), naamlik huishoudelike kombuisafval (HS), skool-kombuisafval (SS), restaurant-kombuisafval (RS) en groothandelaar-kombuisafval is doelgerig geselekteer(WS). Data is ontleed deur gebruik te maak van Stata 15.0 en SPSS V28.0 statistiese sagtewarepakkette. Statistiese betekenisvolheid is gestel op $\alpha = 0.05$ vir alle ontledings. Die meeste van die vrylopende varke (90%) het parasiete gehad, insluitende *Haematopinus suis, Sarcoptes scabiei, Ascaris suum, Fasciola hepatica, Trichuris suis, Strongylids, Coccidia spp., Moniezia expansa* en *Siphonaptera spp*. Die meeste vrylopende varkboere (93.5%) het buitestedelike boerdery beoefen sonder die plaaslike owerheid se goedkeuring, en 72.6% is nie geregistreer vir diere-identifikasie nie. Die meeste boere (94.35%) het nie sanitêre maatreëls geïmplementeer nie, en was nie bewus van grens-oorstrydende diere- en zoönotiese siektes nie (87.1%). HS en SS het ’n hoër voginhoud gehad (80.14% en 80.27% onderskeidelik) in vergelyking met RS en WS (54.36% en 56.63% onderskeidelik). Terselfdertyd het HS en SS ’n laer DM-inhoud (droë materie-inhoud) (19.86±8.21 g/kg DM en 19.73±6.94 g/kg onderskeidelik) gehad in vergelyking met RS en WS (45.65±27.57 g/kg en 43.37±25.45 g/kg onderskeidelik). Alle boere het vir hulle varke varkspoeling gegee, en die meeste boere het vir hulle varke onbehandelde varkspoeling gegee (92.7%). ’n Paar boere het tuisgemaakte voere (26.6%), alternatiewe voere (25%) en konvensionele voere (12.1%) gegee. Bevindings hier steun die aftakeling van die bestaande buitestedelike vrylopende varkstelsel, en om dit te omskep in ’n gekontroleerde, beperkte stelsel om biosekuriteit te bevorder. Die boere moet aangemoedig word om ’n koöperatief te vorm om die oorplasing van die bestuur van vrylopende varke te fasiliteer. Bykans alle vrylopende varke (90%) het

een of meer van die nege geïdentifiseerde parasiete gehad. Die voedingswaarde van varkspoeling wat as voer vir die klein varkies en gespeende varke in die vrylopende varkproduksie gebruik word, kan verbeter word deur die voedingsryke WS met die minder voedingsryke HS varkspoeling te kombineer. ’n Kombinasie van SS en RS kan ook aangeneem word om ’n ideale dieet vir groeiende varke te kry.

Sleutelwoorde: gastro-intestinale parasiete, ektoparasiete, zoönotiese siekte, varkproduksie-stelsels, voedselsekuriteit, voedingsamestelling, kombuisafvalvoeding, varkteelt, proksimale analise, biosekuriteit

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Farming with free-roaming pigs in peri-urban areas is becoming more common in several countries including South Africa (Cofie *et al*., 2003; Carter *et al.*, 2013; Kambashi *et al*., 2014; Ström *et al.,* 2017). This method of livestock farming is known as peri-urban animal agriculture, which involves rearing animals in peri-urban areas, and is often linked with livelihood support and food security for poverty-stricken individuals. According to Statistics South Africa (2018), Mpumalanga province in South Africa has a 33.2% unemployment rate, making it the third highest in the country. Thus, peri-urban agriculture is gaining popularity in South Africa due to rapid population growth, and high poverty and unemployment rates. As a result, individuals are forced to adapt by starting up enterprises such as peri-urban pig farming. It is believed that rearing pigs in peri-urban areas augments household food production and boosts food security within the community (Cofie *et al*., 2003; Chauhan *et al.,* 2016; Montsho and Moreki, 2012; Thomas *et al.*, 2013).

According to the Food and Agriculture Organisation (FAO) of the United Nations (2018), farmers are switching from ruminant farming to mono-gastric animal husbandry due to a scarcity of resources such as land for grazing. For example, while farmers can effectively rear a substantial number of monogastric animals on a small piece of land, ruminant livestock need large expanses of land to thrive.

The free-roaming pig production system is popular in the peri-urban areas of Mpumalanga province. The system has gained popularity due to the predicament of land ownership that ordinary South African farmers encounter. Moreover, it has been found to be a cost-effective and uncomplicated approach to rearing pigs. Pigs reared under the free-roaming system have the freedom to roam and explore without any restrictions, to search for food as well as participate in random mating activities. Thomas *et al.* (2013), confirmed that free-roaming pigs have the ability to cover a distance of around 4.3 km during the day and up to 4.5 km at night. Roaming lengthy

distances without supervision increases the risk of theft and death due to scavengers and wild animals (Kagira and Kanyari, 2010).

However, pigs reared under the free-roaming system play a significant role in the transmission of diseases among both livestock and people. The free-roaming behaviour exposes the pigs to pathogens (Payne *et al*., 2021). Human activities are the primary cause contributing to disease emergence in free-roaming pigs as they have unrestricted access to peri-urban areas such as waste sites, sewerage sites, open fields, and roadways (Jones *et al*., 2013). In addition, these authors indicate that the free-roaming pigs may come into contact with wild and/or diseased pigs, infected human faeces, vehicles, contaminated water, and polluted waste, both directly and indirectly. In addition, the changes in environments and land use, urban growth, and international trade and travel (Jones *et al*., 2013).

Published research has linked free-roaming agricultural systems to a higher prevalence of diseases in both humans and animals, as well as environmental health issues and inadequate management (Lañada *et al.*, 1999; Gerber *et al*., 2005; Burkholder *et al*., 2007; Koneswaran and Nierenberg, 2008). The FRP system may lead to the significant onset of crucial diseases, including African Swine Fever (ASF), Classical Swine Fever (CSF), helminthiasis, mange, *trichinosis*, *cysticercosis*, Foot-and-Mouth Disease (FMD), and *Salmonella* (Thomas *et al.,* 2013; Dione *et al.,* 2018; Garrido *et al*., 2021; Payne *et al.,* 2021). These diseases can impose significant economic burdens due to increased pig mortality and culling expenses, local and international trade limitations, disease control costs, food security concerns, and animal welfare issues (Jones *et al*., 2013; Brown *et al*., 2020; Ruiz-Saenz *et al*., 2022).

To mitigate the threat of pandemics and epidemics resulting from emerging infectious diseases and to lessen their impact on the human and animal population, the development of a strategic framework adopting a One Health approach is required (UNICEF, 2008). This study on free-roaming pig farming will contribute to "One World, One Health," which focuses on the recognition that humans, animals, and the environment are interconnected, signifying an increased awareness of the relationship between the environment, zoonotic diseases, and public health.

Mpumalanga province in South Africa is highly vulnerable from both a public health and socio-economic perspective due to the widespread practice of feeding pigs on swill. Over 47% of smallholder farmers in Mpumalanga province feed their pigs on swill and household leftovers (Munzhelele, 2015).

Swill refers to leftover food from households, hospitals, restaurants, and hotels, as well as fruits, vegetables, and dairy products. Additionally, it includes waste, decomposed food, expired food, and incorrectly labelled food. The Animal Diseases Act, Act 35 of 1984, regulates the feeding of swill. This legislation highlights the requirement for the boiling of swill for one hour to eliminate the microorganisms that can potentially injure or make pigs sick.

In accordance with the mandated biosecurity standards in South Africa, as well as in other places, it is advisable to refrain from feeding swill to pigs (Food and Agriculture Organization of the United Nations/World Organisation for Animal Health, 2010). The practice of feeding uncooked swill can significantly contribute to the introduction of pathogens leading to the occurrence of disease epidemics, including but not limited to botulism, African swine fever (ASF), and various other diseases. Furthermore, the provision of swill as feed usually results in suboptimal physiological development, thereby impeding the farmers' ability to successfully market their pigs at an optimum price in the local market. Moreover, the excessive expenses associated with the abattoir procedure pose a significant difficulty for smallholder pig farmers. Instead, farmers choose to engage in household slaughter without subjecting the animal to inspection by authorized professionals, such as veterinarians and animal technicians (Montsho and Moreki, 2012; Munzhelele, 2015). The practice of slaughtering animals at home and selling uninspected pork poses a significant risk to public health.

Although pigs are generally provided swill as their primary nutrition source, it lacks a balanced nutritional value for use as pig feed (Kagira and Kanyari, 2010; Mutua *et al*., 2012). Pigs of varying ages should receive varying levels of nutrients but when fed swill, all age groups receive feed with the same nutritional composition. Pigs in peri-urban settings typically roam freely and receive feeds such as swill to reduce feeding costs.

The practice of allowing pigs to roam freely and feeding with swill is critical to exposing pigs to parasites. In the process of obtaining nutrition, the pigs may pick up parasites that reside within or on the host organism (livestock). Such parasites can be classified into two categories: ectoparasites, which live on the exterior of their host, and endoparasites, which live inside their host. Some parasitic worms, such as *Taenia solium*, have zoonotic implications because they show transmission between animals and humans. Studies undertaken in Uganda, Zambia, Mozambique, and the Eastern Cape Province (South Africa) have reported the occurrence of cysticercosis involving *Taenia* in both humans and animals (Mafojane *et al.,* 2003; Krecek *et al.*, 2004; Pondja *et al.*, 2010; Mwape *et al*., 2012; Kungu *et al.*, 2016). *Taenia solium,* a parasitic tapeworm, causes a health disorder known as neuro-cysticercosis. The cyst of Taenia implants in the human brain, causing epilepsy in affected individuals (Pondja *et al.*, 2010). Cysticercosis can occur in the brain and spinal cord of both humans and pigs (Mafojane *et al*., 2003; Mwanjali *et al*., 2013; Trevisan *et al*., 2016).

The peri-urban areas of Mpumalanga province are experiencing water restrictions and malfunctioning sewer systems resulting in people being forced to use abandoned sites as informal toilets. This results in pigs having unrestricted access to human excrement (Mwanjali *et al*., 2013). In these areas, pigs also obtain water from natural sources such as streams, stagnant reservoirs, and springs. However, a study documented a higher concentration of pathogens in water from stagnant reservoirs compared to flowing river water and a concomitant increase in the burden of parasite infection in pigs (Ishagi *et al.*, 2003). Thus, this study aims to comprehensively investigate the production management, nutrition and parasite burdens of pigs reared under the free-roaming system in peri-urban areas of Mpumalanga province, South Africa.

1.2. General research problem statement

Despite the South African Department of Agriculture recommendation for enclosed pig farming in urban and peri-urban settings, in Mpumalanga province, pigs are frequently observed scavenging in open places such as dumping sites, as well as in dwelling areas and roadways in peri-urban areas. Mpumalanga province has recorded multiple outbreaks of African Swine Fever (ASF) in peri-urban areas (Amar *et al*., 2020; SAPPO, 2022). The disease spreads rapidly among pigs in peri-urban areas, rather than farms and rural areas, potentially due to the significant movement of people,

animals, and vehicles. In addition, farmers in Mpumalanga province of peri-urban, free-roaming pigs also utilise swill as animal feed for their pigs. Kagira *et al*. (2010) have previously linked the presence of ASF to the practice of feeding uncooked swill to pigs.

The feeding of uncooked swill to pigs contributes to parasitic infestations (Kagira *et al*., 2010) but there is a lack of comprehensive information about the most common parasites found in pigs reared in peri-urban areas of Mpumalanga province. In addition, the occurrence of diseases in the pigs reared in peri-urban areas of Mpumalanga province is currently unknown. A survey on pigs in the Mpumalanga province by Munzhelele (2015) identified parasitosis as a significant issue in pig farming. However, the specific types of parasites remained unidentified.

It is widely recognized that although pigs are highly resilient, they are vulnerable to disease and parasites and can transmit zoonotic infections. Free-roaming pigs can move about in an unrestricted fashion, gaining access to streams and still dams, where they might defecate and contaminate the water supply, which can lead to pigs acquiring parasites. Regrettably, the streams and still dams in Mpumalanga's peri-urban areas that serve as water sources for pigs are prone to malfunctioning or broken sewerage systems. Thus, these waters might contain various microorganisms, including viruses, bacteria, protozoa, algae, and even eggs of gastrointestinal parasites, which can negatively influence the health of pigs, leading to infections involving pathogens such as *E. coli*, *Salmonella*, and *Leptospira* (SAPPO, 2021).

The local sale of live pigs at home, as well as home slaughter, provides the major market for pigs in Mpumalanga province. However, such pigs may not undergo pre-slaughter inspection (Munzhelele, 2015; Munzhelele, Oguttu, and Fasina, 2016; Thys *et al*., 2016). The Meat Safety Act No. 40 of 2000 (Meat Safety Act 40 of 2000) strictly prohibits home slaughter for the purpose of sale of meat in South Africa. The Department of Agriculture, Forestry, and Fisheries (DAFF) has previously identified peri-urban animal agriculture as a significant contributor to the increased likelihood of infectious diseases and zoonotic infections, which pose threats to both human and animal health. However, there is no evidence of efforts to manage and improve this system.

Diseased animals significantly affect farmers' livelihoods as they adversely influence the livestock market. As indicated, unregulated peri-urban animal farming may contribute to the occurrences of infections such as avian influenza and classical swine fever (Food Agriculture Organization of the United Nations, 2018) and, following a recent outbreak of ASF, the price of pork significantly declined (Eadie, 2023). Thus, infection and disease outbreaks influence the pig market, which is a crucial source of income for unemployed pig farmers. Peri-urban farming is a highly common activity in Mpumalanga province and is expected to continue in the foreseeable future. In view of this, studies that improve understanding of peri-urban free-roaming pig production systems are needed. The combination of the aforementioned concerns necessitates current research on peri-urban pig production.

1.3. Rationale and motivation

Previous studies in South Africa have primarily concentrated on commercial and small-scale intensive pig farming, as well as the associated health aspects. Consequently, there is a shortage of information published on the free-roaming pig, an emerging pig farming system. This is especially true when examining the performance, management, health, limitations, and nutrition in peri-urban areas, taking into account the significant migration of both people and animals. The current study aims to improve the understanding of peri-urban pig production and to suggest effective training tools (training focused on study outcomes such as pig health, swill management, pig management in peri-urban areas, and awareness of zoonotic diseases) for emerging farmers of free-roaming pigs. This will ultimately improve the performance of pigs reared under peri-urban conditions and enhance disease management in free-roaming pig production systems. It is anticipated that the training will aid in the understanding of free-roaming pig disease epidemiology and potentially diminish the incidence of communicable and zoonotic diseases in these areas. The findings of this study can be used to develop a comprehensive risk communication and community engagement strategy for pig farmers that allows the pigs to roam freely. Additionally, the results of this study can be used as baseline data for the wider scientific community through the dissemination of the findings through publication in reputable, peer-reviewed scientific journals.

It is imperative to acknowledge and enhance the comprehension of swill as a nutritional source for pigs. This study aims to establish a scientific foundation for identifying potential areas for enhancement of the nutritional value and health risk of swill feed. The ultimate goal is to enhance the production system, enhance food safety, reduce the burden of health risks through animal-sourced foods, and elevate the conditions of small-scale and free-roaming pig farmers through livelihood transformation. Ultimately, the findings derived from the study will be utilised to propose improvements regarding the performance of free-roaming animals by creating comprehensive guidelines, manuals, and reports, adapted for Mpumalanga province, with potential use in other provinces with similar profiles. Using the whole-of-society approach, the public will be informed about the risks associated with feeding swill to animals and the unintended consequences it has on animal health and the knock-on economic and public health impacts.

There is a shortage of information regarding the parasites that are commonly found in and on free-roaming pigs in the peri-urban parts of the peri-urban area in Mpumalanga province. However, this information is necessary to provide effective ways to control parasites (Kumsa and Kifle, 2014) and to raise awareness within communities (Murrell, Weltgesundheitsorganisation and FAO, 2005). In addition, specifically identifying diseases linked to public health programmes is crucial. This information will aid the Department of Agriculture in formulating strategic plans while also enabling farmers to determine which diseases they should prioritise for treatment. Such information can be formalised into guidelines that detail the incidence of identified parasites and recommend the development of parasite prevention strategies for pig producers in Mpumalanga province.

The revised medium-term strategic framework of 2019–2024 seeks to create vibrant and sustainable communities that are able to contribute towards food security for all (Final Revised MTSF 2019-2024, 2021). There is a need to conduct studies on how peri-urban pig farming can contribute to this outcome. To improve the performance of pig production under a free-roaming system, it is necessary to outline and address the economic limitations associated with peri-urban pig production. Moreover, addressing the socio-economic limitations will motivate the free-roaming pig farmers to improve their farming system.

Free-roaming pig farming is a rapidly expanding agricultural activity occurring in peri-urban areas. The practice of free-roaming pig farming will likely spread throughout various peri-urban areas, regardless of legal barriers. The Department of Agriculture, Land Reform and Rural Development (DALRRD**)** lacks information concerning the management of free-roaming pigs in peri-urban settings. Thus, the Animal Disease Act is irrelevant with regard to free-roaming pig farming but rather concentrates on pigs within controlled areas (redline zones) (Animal Diseases Act, Act no 35 of 1984). Rearing free-roaming pigs may negatively affect the environment, as pigs are natural diggers, and their digging can result in soil deterioration. Furthermore, the manure they produce can generate odours for people living in peri-urban areas, and pig excrement may contaminate water sources such as dams or streams. The peri-urban agricultural system does not currently implement any preventive measures to assist pig farmers and other livestock farmers. The results of this study will be useful in revising the existing recommendations for urban and peri-urban animal agriculture and address some issues of the “One Health” approach, which integrates all aspects of human, animal, and environmental health. In light of this, there is a need for studies that will guide policymakers in developing appropriate policies on peri-urban farming, particularly for pigs.

1.4. Aims, objectives and research questions

1.4.1. Aim of the study

This study aimed to comprehensively investigate the production management, nutrition and parasite burdens of pigs reared under the free-roaming system in peri-urban areas of Mpumalanga Province, South Africa.

1.4.2. Objectives

- To conduct an exploratory analysis of the free-roaming production systems and identify production constraints in peri-urban areas of Mpumalanga province.
- To establish the prevalence of ecto- and endoparasites in free-roaming pigs (FRP) in peri-urban areas of Mpumalanga province.

- To investigate the composition of the different swills and how swill can be reconstituted to meet the nutrient requirements for FRPs in peri-urban areas of GSDM.

1.4.3. Research questions

- What are the major characteristics and production restrictions facing free-roaming pig systems in the peri-urban areas of Mpumalanga Province?
- What is the prevalence of ecto- and endoparasites in free-roaming pigs (FRP) in peri-urban areas of Mpumalanga province?
- What are the nutrient levels across different swill types fed to FRP?
- How swill can be reconstituted to meet the nutrient requirements for FRPs in peri-urban areas of GSDM?

1.5. Significance of the study

This is the first study to investigate the production of free-roaming pigs as well as the nutritional composition of swill used by farmers of free-roaming pigs in peri-urban areas of Mpumalanga province. Additionally, this study has determined the prevalence of internal and external parasites in pigs reared in peri-urban settings. The results of this study will inform the development of policies in the province, offer valuable insights for agricultural advisors and animal health practitioners, and provide useful information for researchers and pig farmers about pig rearing in peri-urban areas.

1.6. Study limitations

The study focused only on peri-urban free-roaming pigs and peri-urban pig farmers in seven different municipalities within the Gert Sibande District Municipality. There was no sampling framework for pig farmers in the peri-urban area and, as a result, sampling and participation in the study depended on recommendation from pig farmers using the snowballing method. In addition, the pig farmers included in the study were those who voluntarily agreed to and signed the conceptual agreement. It is possible these two aspects could have introduced sampling bias. These limitations notwithstanding, findings of the present study can serve as baseline data for future studies that can be used by policymakers and responsible authorities to develop policies and development plans to improve rearing of pigs in the peri-urban areas of the study area.

1.7. Organization of the thesis

There are six chapters in this thesis:

- Chapter 1 includes the background of the study, the overall problem statement, rationale and motivation, the study's aim and objectives, research questions, and significance of the study.
- The second chapter provides a literature review.
- The third chapter describes the parasite burden among peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga Province, South Africa.
- Chapter 4 presents free-roaming pig husbandry practices in a peri-urban setting in Mpumalanga, South Africa.
- Chapter 5 describes the proximate analysis of different swill types fed to free-roaming pigs in peri-urban areas of Gert Sibande District Municipality in Mpumalanga Province, South Africa.
- Chapter 6 summarises the conclusions and recommendations of the study.

1.8. References

Amar, S., De Boni, L., de Voux, A., Heath, L. and Geertsma, P., 2021. An outbreak of African swine fever in small-scale pigs, Gauteng, South Africa, July 2020. International Journal of Infectious Diseases, 110, pp.S44-S49.

Brown, V.R., Miller, R.S., McKee, S.C., Ernst, K.H., Didero, N.M., Maison, R.M., Grady, M.J. and Shwiff, S.A., 2021. Risks of introduction and economic consequences associated with African swine fever, classical swine fever and foot-and-mouth disease: A review of the literature. Transboundary and Emerging Diseases, 68(4), pp.1910-1965.

Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P.S. and Wichman, M., 2007. Impacts of waste from concentrated animal feeding operations on water quality. Environmental Health Perspectives, 115(2), pp.308-312.

Carter, N., Dewey, C., Mutua, F., de Lange, C. and Grace, D., 2013. Average daily gain of local pigs on rural and peri-urban smallholder farms in two districts of Western Kenya. Tropical Animal Health and Production, 45, pp.1533-1538.

Chauhan, A., Patel, B.H.M., Maurya, R., Kumar, S., Shukla, S. and Kumar, S., 2016. Pig production system as a source of livelihood in Indian scenario: An overview. International Journal of Science and Environmental Technology, 5(4), pp.2089-96.

Cofie, O.O., Van Veenhuizen, R. and Drechsel, P., 2003. Contribution of urban and peri-urban agriculture to food security in sub-Saharan Africa. Africa Day of the 3rd WWF in Kyoto, 3.

Dione, M., Masembe, C., Akol, J., Amia, W., Kungu, J., Lee, H.S. and Wieland, B., 2018. The importance of on-farm biosecurity: Sero-prevalence and risk factors of bacterial and viral pathogens in smallholder pig systems in Uganda. Acta Tropica, 187, pp.214-221.

Eadie, J., 2023. 'Many Opportunities Await South Africa's Pork Industry'. *Swineweb.Com - Complete Swine News, Markets, Commentary, and Technical Info* (blog). Available at: https://www.swineweb.com/latest-swine-news/many-opportunities-await-south-africas-pork-industry/. (Accessed: 26 April 2023).

Food Agriculture Organization. 2018. Livestock and Human and Animal Health. http://www.fao.org/.

Food and Agriculture Organization of the United Nations/World Organisation for Animal Health, ed. 2010. Good Practices for Biosecurity in the Pig Sector: Issues and Options in Developing and Transition Countries. FAO Animal Production and Health Paper 169. Rome: FAO.

Garrido, V., Migura-García, L., Gaitán, I., Arrieta-Gisasola, A., Martínez-Ballesteros, I., Fraile, L. and Grilló, M.J., 2021. Prevalence of Salmonella in free-range pigs: risk factors and intestinal microbiota composition. Foods, 10(6), p.1410.

Gerber, P., Chilonda, P., Franceschini, G. and Menzi, H., 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource Technology, 96(2), pp.263-276.

Ishagi, N., Ossiya, S., Aliguma, L. and Aisu, C., 2002. Urban and peri-urban livestock keeping among the poor in Kampala City. Ibaren Konsultants, Kampala, Uganda, p.97.

Kagira, J.M. and Kanyari, P.W.N., 2010. Questionnaire survey on urban and peri-urban livestock farming practices and disease control in Kisumu municipality, Kenya. Journal of the South African Veterinary Association, 81(2), pp.82-86.

Kagira, J.M., Kanyari, P.W., Maingi, N., Githigia, S.M., Ng'Ang'A, J.C. and Karuga, J.W., 2010. Characteristics of the smallholder free-range pig production system in western Kenya. Tropical Animal Health and Production, 42, pp.865-873.

Kambashi, B., Picron, P., Boudry, C., Théwis, A., Kiatoko, H. and Bindelle, J., 2014. Smallholder pig production systems along a periurban-rural gradient in the Western provinces of the Democratic Republic of the Congo. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 115(1), pp.9-22.

Koneswaran, G. and Nierenberg, D., 2008. Global farm animal production and global warming: Impacting and mitigating climate change. Environmental Health Perspectives, 116(5), pp.578-582.

Krecek, R.C., Michael, L.M., Willingham III, A.L. and Schantz, P.M., 2004. Questionnaire results from a community-based project on porcine cysticercosis in the Eastern Cape Province of South Africa. Southeast Asian J Tropical Medicine and Public Health, 35, pp.271-274.

Kumsa, B. and Kifle, E., 2014. Internal parasites and health management of pigs in Burayu District, Oromia Regional State, Ethiopia. Journal of the South African Veterinary Association, 85(1), pp.1-5.

Kungu, J.M., Dione, M.M., Ejobi, F., Ocaido, M. and Grace, D., 2016. *Taenia solium* cysticercosis: Risk factors, perceptions and practices in smallholder pig production systems in Uganda.

Lañada, E.B., Lee, J.A.L., More, S.J., Taveros, A.A. and Cotiw-an, B.S., 1999. The reproductive performance of sows raised by smallholder farmers in the Philippines. Preventive Veterinary Medicine, 41(2-3), pp.171-186. https://www.sciencedirect.com/science/article/pii/S0167587799000422.

Mackenzie, J.S., McKinnon, M. and Jeggo, M., 2014. One Health: From concept to practice. Confronting Emerging Zoonoses: the One Health paradigm, pp.163-189.

Mafojane, N.A., Appleton, C.C., Krecek, R.C., Michael, L.M. and Willingham III, A.L., 2003. The current status of neurocysticercosis in Eastern and Southern Africa. Acta Tropica, 87(1), pp.25-33.

‘Meat Safety Act 40 of 2000.Pdf’. 2024. Available at: https://www.dalrrd.gov.za/phocadownloadpap/Acts/Meat%20Safety%20Act%2040%20of%202000.pdf. (Accessed: 09 July 2024).

Montsho, T. and Moreki, J.C., 2012. Challenges in commercial pig production in Botswana. Journal of Agricultural Technology, 8(4), pp.1161-1170.

Munzhelele, P., Fasina, F.O. and Oguttu, J.W., 2016. Evaluation of the production systems and constraints of smallholder pig farming in three agro-ecological zones of Mpumalanga province, South Africa.

Munzhelele, P., Oguttu, J.W. and Fasina, F.O., 2016. Is a 10-sow unit economically sustainable? A profitability assessment of productivity amongst small-holder pig farmers, Mpumalanga, South Africa. Onderstepoort Journal of Veterinary Research, 83(1), pp.1-11.

Murrell, K.D. and Dorny, P. eds., 2005. FAO/WHO/OIE Guidelines for the surveillance, prevention and control of taeniosis/cysticercosis (p. 139). Paris: World Organization for Animal Health.

Mutua, F.K., Dewey, C., Arimi, S., Ogara, W., Levy, M. and Schelling, E., 2012. A description of local pig feeding systems in village smallholder farms of Western Kenya. Tropical Animal Health and Production, 44, pp.1157-1162.

Mwanjali, G., Kihamia, C., Kakoko, D.V.C., Lekule, F., Ngowi, H., Johansen, M.V., Thamsborg, S.M. and Willingham III, A.L., 2013. Prevalence and risk factors associated with human *Taenia solium* infections in Mbozi District, Mbeya Region, Tanzania. PLoS Neglected Tropical Diseases, 7(3), p.e2102.

Mwape, K.E., Phiri, I.K., Praet, N., Muma, J.B., Zulu, G., Van den Bossche, P., De Deken, R., Speybroeck, N., Dorny, P. and Gabriël, S., 2012. *Taenia solium* Infections in a rural area of Eastern Zambia-a community based study. PLoS Neglected Tropical Diseases, 6(3), p.e1594.

Payne, A., Ogweng, P., Ståhl, K., Masembe, C. and Jori, F., 2021. Spatial-Temporal movements of free ranging pigs at the wildlife-livestock interface of Murchison Falls National Park, Uganda: Potential of disease control at a local scale. Frontiers in Veterinary Science, 8, p.689377.

Pondja, A., Neves, L., Mlangwa, J., Afonso, S., Fafetine, J., Willingham III, A.L., Thamsborg, S.M. and Johansen, M.V., 2010. Prevalence and risk factors of porcine cysticercosis in Angonia District, Mozambique. PLoS Neglected Tropical Diseases, 4(2), p.e594.

Ruiz-Saenz, J., Diaz, A., Bonilla-Aldana, D.K., Rodríguez-Morales, A.J., Martinez-Gutierrez, M. and Aguilar, P.V., 2022. African swine fever virus: A re-emerging threat to the swine industry and food security in the Americas. Frontiers in Microbiology, 13, p.1011891.

South Africa. Department of Planning, Monitoring and Evaluation (DPME), 2021. *Final Revised Medium-Term Strategic Framework 2019–2024*. Pretoria: Government Printer. Available at: 18https://www.dpme.gov.za/keyfocusareas/outcomesSite/MTSF_2019_2024/Final%20Revised%20MTSF%202019-2024%202021.pdf. (Accessed: 18 June 2025).

South African Pig Producers Organisation., 2021. The importance of water quality in pig farming. SAPPO. Available at: https://sappo.org/news/lets-talk-indepth/the-importance-of-water-quality-in-pig-farming/. (Accessed: 15 January 2025).

South African Pork Producers Organisation., 2022. African swine fever (ASF) update: 2022. Available at: https://sappo.org/news/lets-talk-indepth/african-swine-fever-asf-update/. (Accessed: 18 June 2025).

Statistics South Africa., 2018. Statistical Release: Quarterly Labour Force Survey (No. P0211). Available at: https://www.statssa.gov.za/publications/P0211/P02111stQuarter2018.pdf. (Accessed: 09 July 2024).

Ström, G., Andersson Djurfeldt, A., Boqvist, S., Albihn, A., Sokerya, S., San, S., Davun, H. and Magnusson, U., 2017. Urban and peri-urban family-based pig-keeping in Cambodia: Characteristics, management and perceived benefits and constraints. PLoS One, 12(8), p.e0182247.

Thomas, L.F., De Glanville, W.A., Cook, E.A. and Fèvre, E.M., 2013. The spatial ecology of free-ranging domestic pigs (Sus scrofa) in western Kenya. BMC Veterinary Research, 9, pp.1-12.

Thys, S., Mwape, K.E., Lefèvre, P., Dorny, P., Phiri, A.M., Marcotty, T., Phiri, I.K. and Gabriël, S., 2016. Why pigs are free-roaming: Communities' perceptions, knowledge and practices regarding pig management and taeniosis/cysticercosis in a *Taenia solium* endemic rural area in Eastern Zambia. Veterinary Parasitology, 225, pp.33-42.

UNICEF., 2008. Contributing to One world, One health. A Strategic Framework for reducing risks of infectious diseases at the animal-human-ecosystems interface.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Pig farming is a well-established industry in South Africa, but it has expanded over time as a livestock rearing practice. The main factors contributing to this transition are urbanization, climate and weather changes, changes in trends of disease outbreaks, human lifestyle changes, economic development, poverty and social inequality, land use and ecosystem changes, and food diversity changes including increasing consumption of porcine pork.

In addition to commercial pig farming, rural areas were the main sites of free-roaming pig farming. However, this practice is currently extending to urban and peri-urban areas. Nevertheless, despite the aforementioned changes, there remains a scarcity of knowledge regarding free-roaming pigs and their performance in peri-urban areas. This study contributes to an improved understanding of peri-urban pig farming in the Mpumalanga province of South Africa.

2.2 An overview of pig production

2.2.1. Global pig production

Pig farming has a major impact on the economy and the livelihoods of people both locally and globally. Pork is the most consumed meat globally, with 36% of total meat consumption, exceeding poultry at 33%, beef at 24%, and goat and sheep meat at 5% (Richie *et al*., 2023). China is the leading producer of pigs, accounting for 48.7% of global production, and is the largest consumer of pork, comprising 50% of global consumption. The European Union follows with 18.3% in production and 15.7% in consumption, while the United States accounts for 11% of production and 8.7% of consumption, respectively (Pig333, 2024). In terms of exports, the EU accounts for the major share, with 30.9%, the United States at 30.4%, and Brazil at 14.8% (pig333, 2024). In comparison, Africa contributes relatively little, roughly 4.6%, to the global pig population. Nigeria is the largest exporter of pork in Africa, followed by South Africa and Malawi (FAOSTAT, 2023). A potential explanation for the elevated pig population

in Nigeria could be the country's substantial human population. South Africa is regarded as the pioneering nation in Africa for implementing the use of superior breeds in pig farming, which enhances both productivity and profitability (Adesehinwa *et al*., 2024).

Approximately 65% - 80% of the pig population in Africa is reared using traditional and semi-intensive agricultural practices (Mbuthia *et al*., 2015; Weka *et al*., 2021). However, there few studies that focus on the economic impact of free-roaming pigs in Africa. Similar to the situation in the European Union, there is a lack of information regarding free-roaming pigs in urban and peri-urban areas. Nonetheless, outdoor pig-rearing practices are implemented in those countries. The outdoor approaches include both enclosed and unenclosed areas within woodlands and forests, as well as fenced and unfenced segments in pastures or fields, unrestricted structures providing access to fenced yards, and confined buildings with restricted access to fenced yards or runs (AHAW, 2021). Pigs in Africa are permitted free movement within residential areas, with no restrictions placed on their movements or access (Payne *et al*., 2021; Weka *et al*., 2021). This exposes the pigs to an elevated threat of contracting numerous diseases, increased susceptibility to theft and injury, and they may contribute to environmental degradation, and vandalism in residential areas and peri-urban localities, such as parks, roadways and streams.

2.2.2. Pig production in South Africa

In South Africa, pork contributes less than 10% of total meat consumed, whereas beef as well as poultry dominate (Bureau for Food and Agricultural Policy, 2021). According to 2018 data, the pig sector in South Africa accounted for only 0.2% of worldwide pork production, making it a relatively insignificant contributor to the international pork market. Over the past decade, the cost of pork in South Africa has increased by approximately 3.5% per year (Mugido, 2017). The growing demand for pork together with population growth are partially responsible of driving the rise in the demand for pork. According to one report, pork production in South Africa has steadily increased over the previous decade, from 243,000 tons in 2016, 250,000 tons in 2017 to 258,000 tons in 2018 (Bonsu and Mugido, 2018). Future projections indicate a significant increase in pork demand due to its relatively low price, as well as the rising prices of beef and mutton (Mugido, 2017; DALRRD, 2021).

2.2.3. Peri-urban pig farming

Peri-urban agriculture is a significant economic activity that has a crucial impact on household livelihoods and food provision in urban and peri-urban areas (Okello *et al.*, 2015). Peri-urban farming refers to the practice of rearing pigs in areas that are located on the outskirts of urban areas including around garbage dumping sites as well as the streets near town centres (Abdu and Gashaw, 2010; Tekle *et al*., 2013; Tomass *et al.*, 2013; Munzhelele *et al*., 2016). These areas may include plots of land without ownership, as well as areas near public roads, vacant lands and river banks (Cabannes, 2012; Hossain *et al.*, 2012). Peri-urban agriculture, as defined by the FAO (2001), refers to agricultural activities that occur on farms situated in close proximity to urban areas. These farms may employ intensive, semi-intensive, or commercial farming practices. This study, however, focuses on those farmers who practice free-roaming pig farming in and around peri-urban areas rather than on the farms.

Urban/peri-urban agriculture may account for roughly 10% - 20% of the world's food supply ; Cabannes, 2012). Peri-urban areas typically rear poultry, pigs, and rabbits as livestock. The majority of peri-urban residents choose to farm pigs because there is a lack of grazing ground available for ruminant animals (Phiri *et al.*, 2003; Mekuriaw and Asmare, 2014; Chauhan *et al.*, 2016). In addition, pig production necessitates a minimal amount of farming on the same amount of land compared to ruminant livestock (Lekule and Kyvsgaard, 2003). Peri-urban pig farming provides pig producers with the benefit of accessing swill from many sources, including restaurants, hotels, schools, hospitals, and marketplaces. The plentiful supply of readily accessible swill in peri-urban areas makes pig farming economically viable and feasible, even for emerging farmers and those without the initial funds to establish a business. Moreover, the presence of a variety of markets in urban areas as opposed to rural farming has been identified as a driver of pre-urban/urban pig production in these areas (Muhanguzi *et al*., 2012; Kambashi *et al.*, 2014). In contrast, although marketing may seem to be readily available for peri-urban and urban farmers, the unlawful occupation of land for farming is a substantial challenge for local governments (Cofie *et al*., 2003).

A significant number of people are migrating from rural to urban or peri-urban areas due to the high level of poverty and limited economic prospects in rural areas (Mthiyane *et al*., 2022). This may be attributed to urbanization bringing individuals who

may have gained agricultural skills before moving to urban areas. Furthermore, the recent occurrence of porcine disease outbreaks pose a significant risk to peri-urban pig farming, as it is very susceptible to the proliferation of infectious microorganisms. Reported disease outbreaks include listeriosis linked to pork products (Olanya *et al*., 2019; Kaptchouang Tchatchouang *et al*., 2020; Thomas *et al*., 2020) while at the beginning of 2019, Foot-and-Mouth Disease (FMD) was detected in certain areas of the Limpopo, Free State, KwaZulu Natal and Gauteng provinces (Department of Agriculture, Land Reform and Rural Development, 2019). These four South African provinces share borders with Mpumalanga province, as well as countries such as Botswana, Lesotho, Mozambique and Zimbabwe. This can lead to a significant risk of transboundary disease transfer. Moreover, the study conducted by Mokoele *et al*. (2014) explored the perception of farmers who engage in long-distance travel to other provinces to market their livestock as a means of increasing their profits. The transportation of animals from areas with disease outbreaks poses an elevated risk and can result in serious challenges for South Africa as a whole. In addition, the uncontrolled movement of pigs without the appropriate permits from authorized officials is a practice that significantly contributes to the occurrence and spread of disease outbreaks (Munzhelele *et al*., 2021). Noteworthy was the epidemic of ASF in the peri-urban areas of Nkangala and Gert Sibande District Municipality in the Mpumalanga province (DALRRD, 2020). Remarkably, the Ehlanzeni District falls under the redline zone, but it has never encountered or reported an outbreak of ASF despite its proximity to the high-risk location of the Kruger National Park.

2.2.4. The free-roaming pig system

The widespread use of the free roaming pig (FRP) production system is expanding rapidly in emerging economies as a result of rising poverty, urbanization, and a high unemployment rate. Furthermore, the use of a low-input system allows for the rearing and management of pigs with the freedom to roam around to fend for their feed at a lower cost compared to other systems such as semi-intensive and intensive farming (Lekule and Kyvsgaard, 2003; Abdu and Gashaw, 2010; Alfredo, 2015). In addition, there are apparent cost reductions due to inbreeding, feeding, and disease management strategies when compared to other livestock options (Lañada *et al.*, 2005; Mbuthia *et al*., 2015; Motsa'a *et al*., 2021).

However, the hidden costs of free-roaming practices have never been completely understood. For instance, researchers have linked the practice of allowing pigs to roam freely to: elevated death rates, reduced reproductive capacity, limited shelter availability, inadequate feeds, and inbreeding (Lekule and Kyvsgaard, 2003; Papatsiros, 2011; Kithinji *et al.*, 2017). According to Boutsini *et al.* (2014), pigs raised indoors were free from *trichinellosis*, while pigs roaming freely developed various diseases. Moreover, diseases associated with rodents such as *Trichinella spp*., *Toxoplasma gondii*, *Salmonella spp*., *Campylobacter*, and *Leprospira spp*., can be passed to pigs in the outdoor system easily, and these are associated with public health challenges (Papatsiros *et al.*, 2012).

Approximately 65% - 80% of the pigs in parts of sub-Saharan African countries are reared under a free roaming method, which is also known as traditional rearing (Lekule and Kyvsgaard, 2003, Oba *et al*., 2020). According to Krecek and Maingi (2004), 25% of the pigs are allowed to roam freely in areas with inadequate resources. Moreover, in certain areas, pigs are allowed to roam freely during specific seasons (Chiduwa *et al.*, 2008; Kagira and Kanyari, 2010; Bandino *et al.,* 2015; Chenais *et al*., 2019). In Zimbabwe, the free-roaming movement of pigs is limited during the rainy season to prevent crop damage (Chiduwa *et al.*, 2008). Bandino *et al.* (2015) observed that when available feeds were insufficient, roaming pigs often received additional feeds throughout the winter and summer. Okello *et al.* (2015) observed a decrease in the body weight of pigs during a season when they did not receive sufficient feeds.

Furthermore, during the planting season, tethering is a common practice in certain areas. Braae *et al*. (2016) reported that improper tethering can cause damage to the skin, perhaps leading to infection, negatively impacting growth, or even causing death. Furthermore, the act of tethering animals is considered cruelty towards them, as stated in the Animal Protection Act No. 71 of 1962. According to some authors, pigs intended for personal use were typically kept in confinement, whereas those intended for sale were generally permitted to roam freely (Thys *et al.*, 2016). This suggests that pig farmers are aware of the risks associated with allowing pigs to roam freely but deliberately choose to disregard the concerns.

According to reports, some customers have a preference for free-roaming pigs

because they believe that these pigs are raised in a welfare-friendly environment (Miao *et al*., 2005; Papatsiros *et al.*, 2012) and are thought to be antibiotic-free (Dietze, 2011). However, Braae *et al.* (2016) advocated for the prohibition of free-roaming systems in order to prioritize animal welfare and ensure food safety. In comparison to the pigs raised in intensive farming conditions, the behavior of free-roaming pigs appears to be more relaxed (Miao *et al*., 2004). According to Sather *et al.* (1997), European and North American pork businesses have prioritized the implementation of free-range pig production as the main objective. This is because it is considered to enhance the taste and health advantages of pork for human consumption. Boutsini *et al.* (2014) corroborated these findings in Greece and noted that pork from free-roam pigs exhibits superior quality compared to pork from conventionally bred pigs. Additionally, according to Papatsiros *et al.* (2012), consumers were willing to spend up to 30% more on outdoor raised pigs when compared to indoor raised pigs. For instance, Woolworths, a prominent South African retail wholesaler, sources meat from animals raised on pastures and on free-range and without antibiotic treatment. However, Woolworths will buy pigs fed on a regulated free-range method.

Inadequate management of FRP has been identified as the primary reason for failure which, in turn, results in a cost reduction in free-roaming production (Lanada *et al*., 2005; Lee *et al.,* 2005). Poor management includes inbreeding, trading, uncontrolled pig movement, and inconsistent feeding practices. The inbreeding is common due to the mating of boars from the same pig population and the prolonged use of a single boar in the same location over many years. These outcomes cause factors such as low litter size (Nath *et al.*, 2013), poor health (Kithinji *et al.*, 2017), low birth weight, physical anomalies, poor growth rate, and poor weaning weight (Weka *et al*., 2021). Overall, poor management, nutrition, biosecurity and housing typically lead to delayed development, compromised health, inadequate carcass quality, and a significant death rate amongst the pigs (Papatsiros *et al.*, 2012; Chittavong *et al*., 2013).

While there are numerous drawbacks associated with allowing pigs to roam freely, there are also certain benefits for farmers. According to a study by Kambashi *et al.* (2014), farmers involved in intensive farming in the DRC may borrow boars for breeding purposes and then pay for their use. In contrast, under a free-range system, boars breed freely without any restrictions. Nevertheless, studies have shown that

FRPs are more likely to transmit *Brucella suis* compared to pigs kept in confined spaces (Wu *et al.*, 2012). This is due to their unrestricted movement and resultant access to potentially contaminated animals and fomites (Muhanguzi *et al.*, 2012).

Free-roaming pigs expend significant energy foraging for sustenance. According to Thomas *et al.* (2013), they can walk up to 4.1 km during the day and 4.5 km at night. In such cases, the pork obtained from FRP is characterized by its low-fat content, but the profitability is reduced due to the slow rate of pig growth. Even though growth is slow, the free-roaming system and low-to-free feeding have a positive impact on profitability and significantly contribute to poverty alleviation and food safety (Frendberg, 2012). However, publications indicate that confinement of pigs has the advantage of enhancing pig growth leading to increased production as well as effectively limiting the spread of disease (Lekule and Kyvsgaard, 2003; Phiri *et al.,* 2003; Thomas *et al.,* 2013)

2.2.5. Free-roaming pig husbandry practice in peri-urban areas

South Africa has insufficient data on FRPs in the peri-urban areas of the country. Several countries, including Congo (Kambashi *et al.*, 2014), Uganda (Muhanguzi *et al*., 2012; Okello *et al*., 2015) and India (Mohakud *et al.*, 2020) have documented the absence of data on pig rearing in peri-urban areas. Despite the insufficient evidence, the practice of allowing pigs to roam freely in peri-urban areas is an increasing trend in Mpumalanga province and South Africa as a whole. The standard pig farming approach is often referred to as the free-range, traditional system or free-roaming pig system and is considered an organic method of rearing pigs (Miao *et al*., 2004); Papatsiros *et al.,* 2012; Boutsini *et al.*, 2014). In African nations, the practice of allowing pigs to roam freely is more popular than in the European Union (EU). This may be ascribed to the fact that African countries have less effective or non-existent policies directed at regulating the movement of unconfined pigs compared to EU countries (Adesehinwa *et al*., 2024).

2.2.6. Contribution of free-roaming pigs to livelihoods

Free-roaming pig farming enhances livelihoods, contributes towards food security, and provides protein to disadvantaged individuals in the community. It also contributes to creation of employment opportunities and provides essential nutrients such as amino

acids, vitamins and iron (Kambashi *et al.*, 2014; Mokoele *et al.*, 2014; Chauhan *et al.*, 2016; Roesel *et al.*, 2019). Pigs possess superior feed conversion efficiency, they attain maturity at a young age, have a short gestation interval, and thrive in many climatic circumstances, surpassing other livestock species (Lekule and Kyvsgaard, 2003). In addition, pigs have the ability to grow not only when fed costly conventional feeds, but also when provided with other, more economical feed products and low-value waste products.

Products from pig farming include pig fat that is used in religious ceremonies for warding off evil spirits and for cooking purposes (Phengsavanh *et al.,* 2011; Madzimure *et al.,* 2013; Munzhelele, 2015). In addition, producers use pork byproducts such as blood and hair to make blood meal and brushes. In small-scale pig farming, the primary objective is to generate money and provide pork for household consumption (Petrus *et al.*, 2011; Muhanguzi *et al*., 2012; Mutua *et al.*, 2012; Ström *et al.*, 2017). Pig farmers in Cameroon rear pigs as a means of disposing of kitchen and market waste (Fualefac *et al.*, 2014). Pig farming in mixed agricultural operations offers farmers the opportunity to save money on crop manure and participate in organic farming.

Pigs are considered essential livestock in households because they generate income, provide household insurance, and serve as a resource during emergencies (Dietze, 2011; Petrus *et al.*, 2011; Phengsavanh *et al.*, 2011; Kagira *et al.*, 2012; Muhanguzi *et al*., 2012; Carter *et al.*, 2013; Kambashi *et al.*, 2014). In addition, they hold significance in traditional culture and traditional medicine (Okello *et al*., 2015; Djimenou *et al*., 2023). Pig farming generates vital income that covers various household expenses such as food, education, family support, pig care, and other necessary items (Munzhelele *et al*., 2016).

Establishing a FRP system requires a relatively smaller initial investment due to reduced housing costs and more affordable pig purchasing, feeding, and maintenance. Thus, the FRP system provides an opportunity for disadvantaged farmers to participate (Frendberg, 2012; Thomas *et al.*, 2013). Similarly, peri-urban pig farming provides an option for low-income countries (Ström *et al.*, 2017). Researchers have recognized pig farming in peri-urban areas as a crucial economic

activity that generates money, creates employment opportunities, ensures food security, mitigates the effects of droughts, and supplies valuable manure for crop cultivation (Kambashi *et al.*, 2014; Mohakud *et al.*, 2020).

2.2.7. Pig management in small-scale farming

Welfare in pig management should adhere to the five concepts of freedom (popularly called the Five Freedoms of Webster), which include: “freedom from thirst, hunger and malnutrition; freedom from thermal and physical discomfort; freedom from pain, injury and disease; freedom from fear and distress; and freedom to express normal behavior” (Webster, 2016). Various pig production systems often disregard the five freedom principles, and this is also true for free-roaming pig farming. A study by Braae *et al*. (2016) reported that communities are aware of the five freedoms. The regulations pertaining to animal welfare should be publicly accessible and rigorously enforced upon farmers and individuals who undermine the mandatory nature of animal welfare should face penalties (DALRRD, 1962).

The mortality of piglets poses a significant challenge for pig farmers. Diarrhea and the tendency of sows to lay over piglets are the primary causes of piglet mortality prior to weaning (Papatsiros, 2011; Chittavong *et al*., 2013). Meanwhile, Papatsiros (2011) also observed that skin damage contributes significantly to the elevated mortality rate in piglets during FRP production. Some authors have demonstrated that pre-weaning mortality rates varied widely and could be found in certain circumstances to be 16.3% in Uganda (Okello *et al*., 2015), 50% in South Africa (Munzhelele, 2015), and 11% in India (Shankar *et al*., 2009).

Moreover, previous studies have shown that approximately 50% - 80% of piglet mortality occurs within the initial seven days, especially in the first 72 hours post-delivery, a most critical period for piglet survival (Koketsu *et al.*, 2006; Shankar *et al*., 2009). Pig production principles recommend weaning piglets between the ages of 28 and 35 days. Nevertheless, in the context of free-roaming and smallholder pig farming, the process of weaning piglets typically occurs after a duration of two or more months (Chittavong *et al*., 2013; Fualefac *et al.*, 2014; Munzhelele, 2015). This impacts the sow and its reproductive cycle, as lactating pigs do not experience estrus. A well-managed sow in an intensive production can farrow approximately five times in two

years; however, the free-roaming system only allows for a sow to farrow three times in two years.

2.2.8. Profile of pig farmers

Pig production in South Africa is comparable to that which exists elsewhere (Kithinji *et al.*, 2017). While pig farming attracts individuals of diverse races and genders, involvement in pig rearing by females varies between countries. In India, Zimbabwe, and Botswana, there is a higher participation of females involved in pig rearing (Nsoso *et al*., 2000; Petrus *et al.*, 2011; Halimani *et al.*, 2012; Mohakud *et al.*, 2020). In Kenya and Cameroon, the majority of individuals involved in rearing pigs were males (Fualefac *et al.*, 2014; Kithinji *et al.*, 2017). Furthermore, studies in parts of South Africa have confirmed that a higher number of males were involved in pig farming in the Gauteng province (Matabane *et al.*, 2015), Mpumalanga province (Munzhelele, 2015), and Limpopo province (Mokoele *et al.*, 2014). Pig farming requires a significant amount of hard work, particularly in peri-urban areas where pigs are mostly fed wet swill and typically need to be transported using a wheelbarrow, hence the likelihood of piggery being a male-dominated activity. Farmers who reared pigs in peri-urban areas had higher level of secondary education compared to those who reared pigs in rural areas (Fualefac *et al*., 2014; Mohakud *et al*., 2020). Research on pig farming in India revealed that women engaged in FRP farming had a higher level of education (Borah *et al*., 2020).

2.2.9. Common pig breeds reared by small-scale farming

The breeds of pigs reared in urban and peri-urban settings primarily differ from those raised in rural areas (Madzimure *et al.*, 2013). In the Democratic Republic of the Congo, Kambashi *et al.* (2014) reported that the preferred pig breeds were Large White, Piétrain, local Large Black, Landrace, and crosses of exotic breeds. Similarly, in Kenya, the preferred pig breeds were the exotic breeds and their crosses (Kithinji *et al.*, 2017). Research from Uganda found that Large White, Landrace, Camborough, and crossbred pigs of exotic and local breeds were present (Muhanguzi *et al*., 2012; Okello *et al*., 2015). Similarly, studies in Tanzania (Braae *et al.*, 2016) and India (Radhakrishnan *et al.*, 2018) reported the presence of Large White, Landrace, whose crosses were predominant. In Cameroon, Fualefac *et al*. (2014) reported crossbred pigs of local and exotic breeds, and Chimonyo *et al*. (2010) reported the use of

Windshyer and Mukota pigs in Zimbabwe. Munzhelele (2015) and Hlongwane *et al.* (2020) reported Kolbroek, Large White, Landrace, indigenous breed and their hybrids in South Africa. However, several studies have found that the free-roaming system includes both local pig breeds and crosses of exotic breeds (Lekule and Kyvsgaard, 2003; Pondja *et al.*, 2010; Papatsiros, 2011; Kagira *et al.*, 2012; Munzhelele, 2015). Furthermore, a substantial number of pig farmers are transitioning from purely indigenous breeds to exotic breeds. This concurs with the findings of Kithinji *et al.* (2017), who highlighted that farmers are gaining an improved knowledge of pig traits. Papatsiros (2011) documented the practice of crossbreeding indigenous boars with exotic breeds in Greece. Crossbreeding indigenous and exotic breeds should enhance productivity, as indigenous breeds have slower development rates compared to the faster-growing exotic breeds (Kadirvel *et al*., 2023). Such crossbreeding resulted in the creation of an efficient and successful pig to improve the genetic composition of pigs.

2.2.10. Pig housing in the peri-urban areas

Pig producers often overlook housing, despite its importance. Providing shelter for pigs is crucial to protect them from extreme weather conditions, in meeting with welfare protocol, to ensure efficient management, and in promoting pig well-being, maintaining hygiene, and preventing the spread of disease. Thus, pig-housing costs are a significant initial capital outlay for pig farmers. Furthermore, given the current state of global climate change, it is imperative to ensure that the pigs have sufficient housing. even if they are constructed using various inexpensive materials (Muhanguzi *et al*., 2012; Munzhelele, 2015). Kagira *et al.* (2010) reported that mud consistently covers the house floor in non-concrete floor situation, posing significant challenges to cleaning and disinfection.

According to Braae *et al.* (2016), the pig shelters often lack adequate roofing to protect the animals from harsh weather. The materials used for constructing walls were concrete, burnt brick, mud brick, and wood (Kambashi *et al.*, 2014). Ugandan research indicated the presence of both traditional mud and grass roof buildings as well as modern dwellings with concrete and corrugated iron roofs (Muhanguzi *et al*., 2012). In contrast, Radhakrishnan *et al.* (2018) detailed the utilization of durable dwellings featuring a solid concrete floor and a roof made of either thatch or tiles. However,

impoverished emerging farmers, lacking the necessary financial resources to establish a business, may choose substandard housing as being cheaper and so more appealing (Lekule and Kyvsgaard, 2003; Mohakud *et al.*, 2020; Chen *et al*., 2022).

Typically, an ideal housing structure should provide protection for pigs from injuries and adverse weather conditions, as well as ensure their safety. Commercial settings house pigs of different age groups separately. However, the FRP system often houses pigs of various age groups together in a sub-standard facility. This has been observed as a worldwide problem (Papatsiros, 2011; Muhanguzi *et al*., 2012; Kagira *et al.*, 2013; Kambashi *et al.*, 2014; Munzhelele, 2015; Munzhelele *et al.*, 2017). Papatsiros (2011) and Kagira *et al.* (2012) proposed that implementing a meticulously planned pig home equipped with a heating system specifically for piglets might effectively decrease pig mortality rates.

Okello *et al*. (2015) proposed the use of environment-controlled housing as a means of enhancing pig productivity in peri-urban locations while Tekle *et al*. (2013) and Banerjee (2018) concluded that housing pigs based on their age and gender offers advantages in terms of management and feeding. This approach promotes pig growth and minimizes competition during eating. Inadequately constructed housing and floors can cause harm to pigs (Braae *et al.*, 2016). Due to these factors, it is crucial to construct pig housing in an efficient manner, and pig farmers should allocate adequate money towards housing in order to enhance their productivity.

2.2.11. Pig nutrition

The main challenge facing pig farming worldwide is the high cost of commercial feeds, which makes feeding swill to pigs, especially in the small-scale and medium-scale production, a more cost-effective option (Kagira and Kanyari, 2010; Katongole *et al.*, 2012; Muhanguzi *et al*., 2012; Tekle *et al*., 2013; Okello *et al*., 2015; Thys *et al.*, 2016; Radhakrishnan *et al.*, 2018; Adesehinwa *et al*., 2024). Within an intensive production system, the expenses associated with commercial feeds make up approximately 70% to 80% of the overall production costs. This is due to the high cost of key feed components and the competition between humans and animals for these resources (Katongole *et al.*, 2012; Muhanguzi *et al*., 2012; Mutua *et al.*, 2012; Ouma *et al.*, 2013; Wadhwa *et al*., 2013; Kanengoni *et al.*, 2015). Furthermore, feed prices fluctuate with

seasons, and feed supply is subject to seasonal and annual variations (Okello *et al*., 2015). Unfortunately, many pig farmers lack sufficient understanding regarding the nutrient formulation of complete meals for various age groups of pigs (Adesehinwa *et al*., 2024). Due to the expensive feed prices, alternative feeds (swill) have grown increasingly popular in many countries and have been carefully documented (Kagira and Kanyari, 2010; Petrus *et al.*, 2011; Frendberg, 2012; Mutua *et al.*, 2012; Ouma *et al.*, 2013; Mokoele *et al.*, 2014; Matabane *et al.*, 2015; Munzhelele *et al*., 2016; Kithinji *et al.*, 2017).

2.2.12. Swill as a feed source

Swill refers to the leftover food waste that is generated from many stages of food production, transit, supply, consumption, and disposal, including rubbish and kitchen waste (Frendberg, 2012; Boumans *et al*., 2022). Food leftovers are generated from household consumption (53%), food processing and packaging (19%), retail and distribution activities (food service, wholesale and markets) (17%), and primary production, involving (post)harvest handling and storage (11%) (Stenmarck *et al*., 2016) There is a lack of information regarding the detailed nutritional value and risks of foodborne diseases associated with pig feeding swill.

Swill is primarily derived from leftovers generated by households, restaurants, schools, hotels, bakeries, abattoirs, food processing plants, fruit and vegetable markets, and other local sources (Frendberg, 2012; Katongole *et al.*, 2012; Tekle *et al*., 2013; Munzhelele, 2015; Chauhan *et al.*, 2016; Munzhelele *et al.*, 2017; Radhakrishnan *et al.*, 2018). Locally available sources such as grasses and animal ruminal substances (Mutua *et al.*, 2012), as well as agricultural byproducts such as banana peels and cabbage leaves are easily accessible (Okello *et al*., 2015).

According to Stats SA (2023), an estimated 1.3 billion tons of food are discarded globally or left uneaten on a daily basis. In Kampala, Uganda, waste materials from restaurants, hotels, workplaces, and bars are gathered and sold as feed for pigs (Frendberg, 2012). However, many foreign materials are commonly found in swill, including plastics, bones, paper, metals, clothes, rubber, and glass (Payne *et al*., 2023). Furthermore, studies have demonstrated that heavy metals significantly affect the quality of pork and the muscles of pigs (Ham *et al*., 2022). According to Jurado *et*

al. (2018), the majority of the significant outbreaks of disease in pigs that were reported to be connected with swill feeding were viral infections - these had a substantial incidence. Bones and meat in swill are the primary sources responsible for the transmission of *Salmonella*, ASF, and Porcine Reproductive Respiratory Syndrome (PRRS), CSF, FMD, and Toxoplasmosis (Frendberg, 2012; Dame-Korevaar *et al*., 2021). In China, the administration of kitchen swill comprising pig products and slaughterhouse waste was noted as a contributing factor to the outbreak of ASF in pigs (Sur, 2019; Zhai *et al*., 2019). The EU prohibits the feeding of livestock with leftover foods containing animal products, as well as waste from catering and kitchens (Jędrejek *et al*., 2016; Zu Ermgassen *et al*., 2018). Given Africa's recurring outbreaks of ASF and FMD, governments should contemplate prohibiting the feeding of food leftovers containing animal products, similar to the practices in EU countries.

Research has reported that swill has high levels of carbohydrates and proteins with an imbalance in nutritional values (Kagira and Kanyari, 2010; Phengsavanh *et al.,* 2010; Mutua *et al.,* 2012; Boumans *et al*., 2022). The nutritional value of food leftovers is considered significant, including both their energy content and overall digestibility (Luciano *et al*., 2020). Research by Jędrejek *et al*. (2016) demonstrated that animal-derived products are frequently well digestible food sources for livestock. The quantity of leftover food will consistently fluctuate, contingent upon availability and the sort of leftovers, which may influence the nutritional value. The imbalanced nutritional value of swill as feed is challenging because different categories and gender of pigs demands different dietary formulations depending on the age and physiological conditions of the pigs (Lemke *et al.*, 2007; Phengsavanh *et al.*, 2011). In addition, feeding younger pigs along with heavier older pigs increases feed competition, leading to uneven development rates among the pigs, to the advantage of the older pigs (Tolosa *et al.*, 2021). Providing pigs with food waste from restaurants and hotels, known for its high protein content (Carter *et al.*, 2013), could potentially lead to this outcome. This was evident when pigs in peri-urban areas of Kenya had a higher average daily gain (ADG) than pigs in rural areas (Carter *et al.*, 2013).

Typically, commercially raised adult pigs receive a daily feed ration of 2–3 kilograms, except for the nursing sow, which may be given more based on the number of piglets being nursed, but the amount of swill they consume remains unquantified. Swill has a

low dry matter content, which means that pigs need to consume a larger volume of swill feeds compared to a ready-made commercial meal (Frendberg, 2012). A low dry matter content indicates a high level of moisture in meals with opportunity for spoilage or rancidity. The swill typically exhibits a moisture content over 80% (Čolović et al., 2019). The wet swill has a reduced level of crude protein (CP) weight for weight compared to the dry feeds (Asar *et al*., 2018; Castrica *et al.*, 2018). Based on their research, wet swill had a crude protein content of 24% and 17.4%, whereas dried swill had a CP of 27.6% and 31.3% (Asar *et al*., 2018). This suggests that dried swill can potentially enhance the growth performance of pigs due to its increased protein content. In addition, Chittavong *et al*. (2013) reported lower levels of calcium, crude protein, and phosphorus in the feed, which did not meet the nutritional requirements for a lactating sow. Frendberg (2012) reported inconsistent findings about lactating sows fed with swill, despite their satisfactory milk production. The investigation of the nutritional value of different types of swill is important for determining the necessary additives to optimize pig performance.

2.2.13. Management of swill fed to pigs

The absence of or partial implementation of biosecurity measures in peri-urban areas, particularly in relation to swill handling and control, poses a significant challenge to pig production. Frendberg (2012) reported that it is necessary to process (heat-treat) or handle swill or leftover food before giving it to pigs. According to the South African Animal Diseases Act (Act 35 of 1984), swill must be boiled for a minimum of one hour in order to eliminate any harmful microorganisms and reduce the risk of disease transmission. This also includes previously prepared meals, such as leftovers from restaurants, hotels, and hospitals. Various sources support this practice (Ermgassen *et al.,* 2018; Janse van Rensburg *et al.,* 2020) and Almeida *et al*. (2014) documented that heat treatment has the potential to improve both the digestibility and the composition of nutrients. In South Africa, untreated swill is fed to pigs, and according to Rametse *et al*. (2020), enforcing treatment of the swill among farmers is challenging. Despite the numerous challenges associated with feeding swill, it remains an increasingly common way of feeding, particularly for pigs. Moreover, swill is often provided to pigs without undergoing any form of processing, as mandated by legal requirements.

2.2.14. Swill as a potential carrier of human/animal diseases.

Based on the findings of Phiri *et al.* (2003) and IFAH (2013), many human infectious diseases are zoonoses that originate from animals. The zoonotic diseases have the potential to cause severe and fatal infections in both animals and humans. Feeding pigs with contaminated kitchen swill, carcasses, and slaughter byproducts promotes disease transmission (Thomas *et al.*, 2013; Sur, 2019). Pigs feeding with swill can significantly contribute to the spread of zoonotic diseases, including hepatitis, avian influenza, and parasites (Dame-Korevaar *et al*., 2021). Furthermore, the pigs reared under free-roaming conditions are more likely to spread zoonotic infections and diseases such as *Trypanosomiasis, Cryptosporidiosis, Sarcocystosis, Blastocytosis,* and *Taenia solium* since they are likely to come in contact with many environmental contaminations in the course of their wandering around for foods (Thomas *et al.*, 2013; Thys *et al.*, 2016). With the establishment of an outbreak, especially the transboundary fast-spreading and trade-sensitive diseases such as ASF, this necessitates the slaughter of a substantial number of pigs, leading to significant economic losses. In addition, Pondja *et al.* (2010) and Thys *et al*. (2016) indicated that free-roaming pigs are more susceptible to zoonotic diseases compared to confined pigs resulting from poor feeding and nutrition and scavenging opportunities, which expose them to a various of hazards.

2.2.15. Health challenges of the free roaming pigs

The primary health issues in pig farming arise from farmers' insufficient knowledge of pig management (Matabane *et al.,* 2015; Munzhelele *et al*., 2015; Munzhelele *et al*., 2017, Adesehinwa *et al*., 2024). Parasitosis is a significant health issue in pig farming, particularly because the majority of smallholder pig farmers do not administer deworming treatment to sick pigs (Kagira *et al.*, 2012; Thanasuwan *et al*., 2024). This may be due to the exorbitant costs of pharmaceuticals or the prevalent use of ethno-veterinary products (Muhanguzi *et al*., 2012; Nath *et al.*, 2013; Munzhelele *et al*., 2016). Nevertheless, several farmers have administered oxytetracycline and ivermectin as a general treatment for various diseases without identifying the specific cause of the disease (Fasina *et al.*, 2012; Kagira *et al.*, 2012; Mokoele *et al.*, 2014; Munzhelele *et al*., 2016).

Furthermore, several farmers lack the ability to distinguish between vaccination and

treatment, and some even make unsupported assertions about using non-existent vaccinations like the ASF vaccine (Kambashi *et al.*, 2014; Munzhelele *et al.*, 2017).

The shortage of veterinary specialists and veterinary infrastructure in the country also adds to the dilemma in the free-roaming pig production system (Tekle *et al*., 2013; Munzhelele, 2015; Thanasuwan *et al*., 2024). Insufficient equipment and inadequate veterinary management has a negative impact on animal health, leading to poor carcass quality or damage to the carcass at slaughter as a result of improper animal handling (Papatsiros *et al.*, 2012). This results in the impractical administration of medication or vaccination to fully-grown pigs, particularly in the context of pig farming. As Papatsiros (2011) stated, ensuring effective management of a herd's health is critical in free-range production for the control of zoonotic diseases and the country's food safety. Nevertheless, pig producers under a free-roaming system tend to overlook the maintenance of their pig herds' health. Papatsiros *et al.* (2012) highlighted the importance of maintaining excellent herd health and wellbeing as fundamental aspects of free-roaming pig farming.

2.2.16. The challenges posed by parasites in pigs

Pig productivity is limited by ectoparasites such as mange and lice, as well as endoparasites such as worms. Many investigations have identified parasites as the primary factor limiting pig productivity in different countries (Mhoma *et al*., 2012; Muhanguzi *et al*., 2012; Madzimure *et al.*, 2013; Tekle *et al*., 2013; Thomas *et al.*, 2013; Odo *et al.*, 2016; Thanasuwan *et al*., 2024). Parasite infestation is a significant challenge for pig farmers across different pig production systems. Gastrointestinal parasites cause debilitation and diarrhoea, leading to decreased weight gain and production losses (Nsoso *et al*., 2000; Lee *et al*., 2022). The presence of a large number of parasites in pigs results in significant financial losses for pig farmers because it hinders weight gain and leads to the rejection of carcasses or parts thereof during the slaughter process (Stewart and Hale, 1988; Tomass *et al.*, 2013).

Ascaris suum, Crytosporidium spp.*, Fasciola hepatica, Entomoeba* spp.*, Strongylid nematodes, Balantidium coli, Coccodia oocyst, Trichurus suis,* and *Trichostrongylus* spp. have all been linked to disease outbreaks and insufficient disease control (Nsoso *et al*., 2000; Thomas *et al.*, 2013; Tomass *et al.*, 2013; Geresu *et al.*, 2015; Jufare *et*

al., 2015; Lee *et al*., 2022). The presence of parasites in pigs contributes towards a risky image for the FRP rearing system in the public and marketing sectors (Geresu *et al.*, 2015).

Parasitic helminths pose problems as the complicated nature of infection escalates between animals and humans (Tomass *et al.*, 2013). They especially cause human *cysticercosis* (Thys *et al.*, 2016). In addition, ova/oocysts have a negative impact on the reproductive capabilities of female pigs, leading to poor reproduction (Geresu *et al.*, 2015).

Pigs primarily harbor the parasite *Coccidia*, which poses a threat to both humans and animals (Lee *et al.*, 2005; Abdu and Gashaw, 2010; Jufare *et al.*, 2015; Nwafor *et al*., 2015; Roesel *et al.*, 2019; Gong *et al.*, 2021). Pigs infected with this parasite experience non-haemorrhagic diarrhoea, which can cause dehydration, a rough coat, loss of weight, weakness, and even death (Nwafor *et al*., 2015; Dione *et al.*, 2018; Gong *et al.*, 2021). Munzhelele *et al.* (2024) identified several factors that significantly increased the occurrence of *coccidia*. These factors include the practice of feeding pigs with dead chicken, the frequent use of feeders without proper cleaning, and the use of drums for storing swill. However, Muhanguzi *et al*. (2012) emphasized that in order to enhance production, it is crucial to enhance disease control, housing, feeding, and breeding strategies.

Ectoparasites are organisms that reside on an animal's skin and obtain nutrition by extracting blood from the host. Multiple studies have identified ectoparasites as a significant challenge in pig farming in Ethiopia, Kenya, Cameroon, and Nigeria (Abdu and Gashaw, 2010; Kagira *et al.*, 2013; Fualefac *et al.*, 2014; Odo *et al.*, 2016), respectively. In the study by Okello *et al*. (2015), pigs raised indoors had a much lower incidence of ectoparasites than those reared outdoors (24% versus 84% prevalence). Free-roaming farming is highly conducive to parasite infections (Abdu and Gashaw, 2010; Kagira *et al.*, 2013; Okello *et al*., 2015). According to Odo *et al.* (2016), adult female pigs had a higher prevalence of ectoparasites compared to young piglets. Furthermore, Hale and Stewart (1979) demonstrated that pigs devoid of ectoparasites experience an approximate 35% acceleration in growth and a roughly 23% weight increase compared to pigs afflicted with parasites.

Primary ectoparasites afflicting pigs include mites, lice, ticks, and fleas, specifically *Sarcoptes scabiei* and *Haematopinus suis* (Damriyasa *et al.*, 2005; Papatsiros *et al.*, 2012). The ecto-parasite sustains itself by extracting blood through its feeding mechanism, leading to sensations of itchiness and discomfort in the skin. This, in turn, leads to hair loss, the formation of blisters, and a decline in the overall performance of pigmentation (Kagira *et al.*, 2013). Studies published by Sanchez Botija and Badiola (1966), Doster (1995), Permin *et al.* (1999), Damriyasa *et al.* (2005) and Riyesh et al. (2016) established a connection between *H. suis* and ASF, *eperythrozoonosis*, and swine pox. In addition, ectoparasites are recognized for their ability to induce pruritus and anaemia and have been associated with the emergence of *Mycoplasma suis.* (Nsoso *et al*., 2000; Damriyasa *et al.*, 2005). Training on controlling parasites is necessary to educate farmers about health factors that compromise their operations and profits.

The incidence of ectoparasites in pigs often differs across various age and gender categories. A study in Kenya and elsewhere found no gender disparities in the frequency of *Haematopinus suis*. However, research showed that female pigs had a higher prevalence of *Sarcoptes scabiei* (65.6%), while male pigs had a higher prevalence of ticks (Kagira *et al.*, 2013). The *H. suis* was prevalent in pigs of all age groups (Damriyasa *et al.*, 2005). According to Kagira *et al.* (2013), there is a significant prevalence among the finishing group in terms of age. According to Odo *et al.* (2016), *Sarcoptes scabiei* was highly prevalent in pigs aged 2 to 8 months. Pigs are highly susceptible to ectoparasites due to factors like unrestricted movement, inadequate animal care, lack of parasite treatment, or irregular medication administration (Permin *et al.*, 1999; Kagira *et al.*, 2013). Mhoma *et al*. (2012) conducted a study in Mwanza, Tanzania, and found that effective management led to a reduced prevalence of ectoparasites. This provides conclusive evidence that efficient administration of anti-parasitic drugs reduces the number of parasites.

Breed preference presents a significant challenge in pig production, as the primary determinant of breed preference is productivity, not disease resistance. Munzhelele 2015) reported that a study in the Mpumalanga area of South Africa revealed the use of indigenous breeds and crosses of exotic breeds. Exotic breeds are well suited for intensive farming and require diligent maintenance in order to thrive and achieve

outstanding health. Indigenous breeds outperform exotic breeds in free-roaming pigs due to their '*potentially higher*' disease resistance (Halimani *et al.*, 2012). Papatsiros *et al.* (2012) study in Greece, identified issues such as leg injuries, reproductive difficulties, reported on the suboptimal physical state among exotic pigs and their crosses on sows in a free-roaming system. Sows afflicted with leg injuries are unable to assume a standing position for mounting, resulting in suboptimal conception rates or the complete absence of pregnancy. Leg injuries and poor physical health can result from the need of free-roaming pigs to forage for sustenance and water. To prevent limb injuries and poor body condition in free-roaming pigs, it is advisable to use indigenous pigs, which are adapted to the environment. These pigs are resilient and better equipped to withstand harsh climatic circumstances compared to foreign breeds (Halimani *et al.*, 2012).

2.2.17. The causes of mortality in pig farming

The farmer should strive to reduce mortality in pigs to the barest minimum, as it limits the profitability of pig farming. The main causes of mortality in piglets are typically malnutrition, exposure to extreme temperatures, cannibalism, diarrhoea, dystocia, and layover by sows (Papatsiros, 2011; Chittavong *et al*., 2013; Madzimure *et al.*, 2013; Fualefac *et al.*, 2014). It is crucial to control diseases in pig husbandry (Kagira and Kanyari, 2010). During an ASF outbreak, a significant number of pigs are culled through killing as a control measure, rendering ASF the predominant disease (Kambashi *et al.*, 2014). An ASF typically occurs due to failed biosecurity implementation by farmers, pig handlers and stakeholders in the pig value chain. Apart from the direct impact on the farm, such outbreaks affect the overall operationalization of the value chain. For instance, an outbreak in part of the study areas forced the suspension of this study for a period. The ASF disease pandemic impacted four municipalities within the Gert Sibande District Municipality. In addition, the farmer's pigs were purchased at a reduced price in order to be culled as a form of recompense. Nevertheless, the price was lower than the prevailing market price, causing the farmers to feel discouraged about continuing pig farming in the future. In a FRP system, pigs have a tendency to roam in bushes, which exposes them to contact with rodents and wild animals. In addition, inadequate management of pig manure and food waste may attract rats and other animals to the pigsty and lead to disease spread (Ström *et al.*, 2017). Papatsiros *et al.* (2012) stated that rodents pose a significant risk

to public health such as *Trichinella and Toxoplasma gondii*.

Effective strategies such as vaccinations (where feasible), health interventions for diseased pigs, and strict biosecurity protocols can significantly decrease the mortality rate on pig farms. Proper handling and storage of vaccines are crucial, as improper handling and storage can result in decreased effectiveness and protection. Moreover, the improper administration of treatment to sick pigs, specifically the inappropriate dosage per kilogram, can result in pig mortality within the pig farming industry (Kagira *et al.*, 2012). Furthermore, reports have indicated inadequate proficiency in identifying diseased animals, inaccurate diagnosis, and the use of inappropriate medicine for specific diseases (Braae *et al.*, 2016). Engaging in pig health and management training can yield significant insights for pig farmers to enhance their production outcomes.

2.2.18. Public health implications of backyard or home slaughter

The prohibition of pigs in specific marketing areas results in an increase in home slaughter for sales (Munzhelele *et al*., 2021). Published results show that pigs that were fed swill that contains 50% food waste resulted in 13% lower growth rates; hence, the swill-fed pigs that the farmer raises will require 13% more time to attain the weight required for slaughter (Ze Ermgassen *et al*., 2016). Furthermore, free-roaming encourages pigs to utilize excessive energy in search of food, which may impede their growth. Due to the poor growth and poor health condition of pigs reared under free roaming systems, farmers are not able to have their pigs slaughtered at professional abattoirs. As a result, many of the pigs raised informally get slaughtered at home or in the backyard (Stewart and Hale, 1988; Munzhelele *et al*., 2015). In addition to pig parasites leading to decreased productivity, smaller litter sizes, lower birth weights, higher mortality rates, slower growth rates (Holness, 1991; Sowemimo *et al.*, 2012; Pattersson *et al*., 2021), they also lead to increased condemning of carcasses (Stewart and Hale, 1988; Pattersson *et al*., 2021). Furthermore, due to concerns and fear of criticism for selling poor-standard pigs, free-roaming pig owners opt to bypass meat inspectors and establish their own facilities. As a result, they limit their sales to informal facilities (Molotsi *et al*., 2021).

Studies have documented illegal slaughtering of unhealthy pigs at unauthorized sites,

where pigs are slaughtered at households despite the fact that selling home-slaughtered meat is prohibited by law (Munzhelele, 2015; Munzhelele *et al*., 2016). Several other countries have reported similar findings (Pondja *et al.*, 2010; Muhanguzi et al., 2012; Ouma *et al.*, 2013; Thys *et al.*, 2016). The farmers engage in the practice of slaughtering unhealthy pigs to prevent financial losses (Munzhelele *et al*., 2016; Thys *et al.*, 2016). In addition, due to the lack of inspection procedures, home slaughter significantly increases the risk of disease transmission (Pondja *et al.*, 2010). According to Papatsiros *et al.* (2012), the lack of available slaughterhouses in some areas forces farmers of FRPs to slaughter the pigs at home or on their privately owned property without proper pre-inspection of the pigs.

There is an ongoing issue of insufficient or inadequate information among pig producers. For example, some farmers have the belief that when an animal is sick, the disease(s) only impact the blood and not the carcass (Thys *et al.*, 2016). The primary factors contributing to poor performance of pigs and the negative impact on public health are a consequence of the lack of adequate understanding of topics such as feeding, animal disease, and animal breeding (Chauhan *et al.*, 2016). Due to the lack of expertise, farmers are engaging in both home slaughter and local slaughter. This aligns with the research conducted in Kenya, where pigs were slaughtered and subsequently sold within the local market (Kithinji *et al.*, 2017). Meat inspection functions as a tool to collect data on diseases that require reporting, diseases that can spread from animals to humans, and diseases that are commonly found in livestock.

Infectious diseases account for over 26% of all documented human mortality worldwide, with zoonotic diseases accounting for over 70% of these cases (Bartram and Carr, 2004; Kagira *et al.*, 2010). Consumption of contaminated food, poor hygiene practices by handlers, unwashed fruits and vegetables, and the consumption of undercooked infected meat, particularly pigs, often transmit zoonotic infections (Mwape *et al.*, 2012; Mwanjali *et al.*, 2013). Transmission of zoonotic diseases can also occur through indirect contact via water, food, and environmental pollution (Bartram and Carr, 2004). Free roaming pigs that search for food might spread diseases because they consume human faeces, drink water that contains parasite eggs, and come into contact with products that originate from pastures and crops irrigated with sewage (Geresu *et al.*, 2015; Thys *et al.*, 2016).

2.2.19. Pig production-marketing strategies

According to the 2020 report from the pig sector in South Africa, the country imports approximately 16 091 tons of pork (DAFF, 2021). The importation of this pork highlights a gap that requires attention. Furthermore, this suggests that in order to reduce pig imports, there is a need to increase pig production in South Africa. The expanding market in the surrounding farming areas is driving the steady growth of pig production in peri-urban areas. Several studies in South Africa have analyzed the difficulties associated with marketing pigs (Antwi and Seahlodi, 2011; Khapayi and Celliers, 2016; Munzhelele *et al.*, 2021). Inadequate management, inadequate sanitation, and unrestricted movement pose a significant threat to the pig production sector since they contribute to the spread of infectious diseases amongst the pigs. The latest outbreaks of ASF in the peri-urban areas of Mpumalanga province resulted in the closure of auction markets throughout the province. Consequently, butchers and abattoirs were the only buyers of pigs. Before transporting pigs to abattoirs and butcheries, a state veterinary surgeon has to inspect the animals and issue a movement permit.

According to Munzhelele (2015), only 14% of pig farmers in the province of Mpumalanga chose to sell their pigs to abattoirs. However, a more recent investigation in the Redline area of Mpumalanga province revealed a 21% increase in sales to abattoirs (Munzhelele *et al.*, 2021).

The primary problems in marketing pigs include insufficient information such as pig market price per kilogram, branding and packaging, inadequate negotiation skills, limited financial resources, and the capacity to meet the specific requirements and standards set by regulatory bodies. The aforementioned shortcomings compel farmers to locally dispose of their pigs, often resorting to household slaughtering and selling live pigs at home at very low prices (Mokoele *et al*., 2014).

Uncontrolled roaming by pigs has a significant impact on pig marketing and several studies have documented the practice (Kagira and Kanyari, 2010; Katongole *et al.*, 2012; Muhanguzi *et al*., 2012; Munzhelele *et al.*, 2021). The primary challenge in FRP is inadequate pig management, which results in a poor final product. According to Phiri *et al.* (2003), zoonotic diseases, including *leptospirosis, brucellosis, tuberculosis,*

Japanese B encephalitis, trichinosis, cysticercosis, and *salmonellosis* pose significant challenges due to inadequate disease control measures and a shortage of animal health officers for meat inspection in slaughterhouses.

2.2.20. Importance of biosecurity in pig farming

Pig farming is heavily reliant on the implementation of biosecurity, which refers to the methods or measures implemented to protect both humans and animals from the introduction and transmission of disease-causing pathogens (FAO/WB/OIE, 2009). Inadequate management practices and insufficient biosecurity measures contribute to the transmission of diseases such as ASF and FMD, particularly in peri-urban areas (Praet *et al.*, 2010; Kambashi *et al.*, 2014; Munzhelele, 2015). The transmission of these diseases occurs through direct and indirect contact due to free-roaming and uncontrolled pig movement, resulting in an increased frequency of various outbreaks that can potentially reduce the country's exports (Montsho and Moreki, 2012).

In pig production, implementation of biosecurity measures is not only to mitigate the risk of zoonotic diseases, but also to prevent the transfer of significant diseases between animals. For example, ASF has become common in peri-urban areas of Mpumalanga province where there have been reported cases of ASF outbreaks in 2012, as well as more recently in 2019 and 2020 (DALRRD, 2020). Moreover, the province of Limpopo, adjacent to the province of Mpumalanga, has detected FMD in cattle. Of note is that FMD is a zoonotic disease that can also affect pigs. In the absence of effective biosecurity measures, the aforementioned diseases, as well as certain communicable diseases, can rapidly propagate.

Increased human-livestock interactions and the growing migration of people in and out of rural, peri-urban, and urban areas facilitate the spread of infections (IFAH, 2013). The Mpumalanga province shares a border with two neighboring countries, Swaziland and Mozambique. Furthermore, a segment of Kruger National Park is located within the Mpumalanga province. It is well established that national parks harbor wild animals that serve as potential vectors for diseases. In this case, wild pigs serve as reservoir hosts of ASF, whereas buffaloes serve as carriers of FMD (Vosloo *et al*., 2002). Thus, ASF presents one of the highest risks, significantly influencing the pig sector. Pigs in other parts of Africa have tested positive for Tuberculosis (TB). This indicates that

there are ambiguities and possible risks associated with the practice of rearing pigs, which can have negative implications for the general population and public health (Arega *et al*., 2013). Inadequate biosecurity measures contribute to this, as the consumption of infected swill from hospitals or household leftovers can transmit TB.

Okello *et al*. (2015) and Mohakud *et al.* (2020) outlined the need to adhere to biosecurity procedures, which include preventing acquisitions from suppliers that do not adhere to biosecurity practices and are deemed to be untrustworthy. Nevertheless, numerous farms disregard the quarantine protocols, potentially leading to a severe epidemic. Furthermore, the practice of free roaming renders the implementation of the quarantine protocol impossible. Previous research has shown that auctions are generally not a reliable method for obtaining breeding stock unless they specifically focus on breeding animals (Munzhelele, 2015). Poor implementation of biosecurity measures poses a significant risk to both public health and the economy. Viral diseases pose a significant risk to food security and result in economic losses (Costard *et al.*, 2009; Fasina *et al.*, 2012; Munzhelele *et al*., 2016). Pig farmers are severely disadvantaged as a result of disease outbreaks (Munzhelele, 2015).

2.2.21. Water contamination and scarcity in peri-urban areas

Climate change has elevated the significance of water as a crucial resource in South Africa and its surrounding areas. The exorbitant cost of water and difficulties in accessing it burden farmers in peri-urban areas (Cofie *et al*., 2003; Muhanguzi *et al*., 2012). Because of this difficulty, streams, dams, and nearby rivers in peri-urban areas serve as the primary or sole sources of water (Kagira *et al.*, 2010; Muhanguzi *et al*., 2012) and wastewater such as sewage (Mazari-Hiriart *et al.*, 2008; Cabannes, 2012). According to the Gert Sibande Municipality District Rural Development Plan, water quality is a significant concern due to inadequate sewage infrastructure maintenance. Additionally, water that is contaminated with human faeces can be a water source for these pigs, which in turn can lead to the spread of diseases like giardiasis, *Taenia solium* and cryptosporidiosis.

In addition, giardiasis is impervious to chlorination and may only be eliminated by means of filtration and boiling (Olson and Guselle, 2000). Waterborne parasite infections are a significant concern in both public health and livestock production,

leading to outbreaks (Olson and Guselle, 2000). Likewise, the improper management of wastewater can potentially pose risks to public health, wildlife, and the environment (Cabannes, 2012). Furthermore, allowing pigs to roam freely poses a significant risk of inadequate environmental cleanliness, and so can facilitate the transmission of parasites to humans and other animals (Tomass *et al.*, 2013).

The scarcity of drinking water for pigs leads to a decrease in feed intake, resulting in poor pig performance (Phengsavanh *et al.*, 2010; Braae *et al.*, 2015). In the gastrointestinal tract, water facilitates the digestion and absorption of nutrients.

According to one of the five freedoms, it has indicated that the owner has a legal duty to make sure the pig stays hydrated and does not go without water (Webster, 2016). Munzhelele and colleagues have documented the restricted access to water for pigs in Mpumalanga province (Munzhelele *et al*., 2016). According to Braae *et al.* (2016), a scarcity of water decreases the rate at which pigs grow because it leads to a reduction in feed consumption. Pig farming necessitates distinct water requirements for pigs of varying age groups. In addition, the climate has a significant impact on water use. Animals drink more water during the hotter months compared to the colder seasons. Braae *et al.* (2016) found that a lack of water for lactating sows can result in inadequate milk production, which in turn can contribute to increased mortality rates of piglets throughout the lactation period. During pig rearing, a lactating sow has the capacity to ingest up to 50 liters of water on a daily basis. Despite the critical role of water in pig rearing, studies have documented instances where no water was available (Phengsavanh *et al.*, 2010; Braae *et al.*, 2016).

The Mpumalanga province is known for its mining industry and harsh climatic conditions, particularly characteristic of the GSDM. As a result, there is a significant amount of precipitation during the summer months. Miao *et al*. (2004) argued that areas characterized by low rainfall should implement free-roaming farming. Irregular rainfall impacts free-roaming pigs, causing a scarcity of forage (Madzimure *et al.*, 2014). Increased rainfall leads to a significant increase in water flow from the land to the dams, resulting in the formation of water pits. Reports indicate that microbiological pathogens contaminate the water from streams (Cofie *et al*., 2003). As a result, the untreated water originating from the old mines and running into the holding dams has

a significant impact on animals' health. Inadequate environmental conditions have a negative impact on the sexual drive, reproductive success, and ability to conceive in pigs (Matabane *et al.*, 2015).

2.2.22. Impact of free-roaming pigs on the environment

The recommendation of the Environmental Assessment Impact (EAI) includes conducting pig farming project approximately 500 meters away from residential areas. However, in the peri-urban parts of Mpumalanga province, keeping of pigs in nearby dwelling houses and allowing them to roam freely without adhering to any specific distance requirements is a common practice. This observation is closely linked with the scarcity of land available for agricultural development. Free-roaming pig management in the peri-urban areas can significantly contribute to reduction of water, soil, and air pollution through their utilization of environmental wastes (Gerber *et al.*, 2005). However, they can also serve as a source of disease transmission for both livestock and humans. Pigs, carrying gastro-intestinal parasites, contaminate the environment with their faeces, while humans can also transmit diseases to animals. According to Abdu and Gashaw (2010) and Tomass *et al.* (2013), pigs infected with gastro-intestinal parasites can likewise contaminate the environment through their faeces.

The FRP system also has a negative impact on environmental sanitation and health. Parasite eggs from pigs may survive for extended periods in soil (Tomass *et al.,* 2013). As a result, managing parasites in free-roam pig systems will be challenging due to the parasites' frequent recurrence from infected soil to infect pigs while they are rooting. In addition, during the rainy seasons, the overflow of parasite eggs into surrounding dams or streams can result in their significantly negatively impacting the health of both the public and livestock. Microbiologic pathogens can contaminate water from streams and dams, as previously mentioned. Consequently, those who rely on this water source may be susceptible to contracting zoonotic parasites. The presence of contaminated manure can contribute to the spread of infections to crops in peri-urban areas. In contrast, according to Cabannes, (2012), peri-urban pig farming contributes to enhancing the atmosphere by recycling untreated waste. Peri-urban manure disposal requires a good drainage system (Umeh *et al*., 2018). In Kerala, India, pig manure was employed in the slurry tank for biogas production

(Radhakrishnan *et al.*, 2018).

Factors that constrain pig production include poor genetic breeding stock, inadequate and poor agricultural and husbandry practices, low productivity, limited knowledge of pig husbandry and management, restricted access to veterinary and extension services, insufficient nutrition, diseases and parasites, pandemic disease outbreaks, water scarcity, free-roaming management pigs, inadequate biosecurity, limited access to agricultural land, restricted access to financial facilities, uncontrolled movement of pigs, inadequate housing, poor hygiene, expensive pig medication and vaccinations, and ineffective marketing (Lekule and Kyvsgaard, 2003; Phiri *et al.*, 2003; Wabacha *et al.*, 2004; Kagira and Kanyari, 2010; Kagira *et al.*, 2010, 2012, 2013; Petrus *et al.*, 2011; Muhanguzi *et al*., 2012; Mutua *et al.*, 2012; Tekle *et al*., 2013; Munzhelele, 2015; Munzhelele *et al*., 2016; Munzhelele *et al.*, 2021). Effectively addressing the aforementioned difficulties can significantly boost pig production, give the pigs improved reproductive capacity and improve their growth due to adequate management, and, at the same time, contribute to addressing the challenges of human and animal health. This approach has the potential to stimulate economic growth and generate employment opportunities. Research on a system for managing FRPs can greatly contribute to controlling the outbreak of diseases, which can significantly contribute to food security, job creation, and agricultural economic growth.

2.3. REFERENCES

Abdu, S., Gashaw, A., 2010. Production system dynamism and parasitic interaction of swine in and around Holetta, Ethiopia. Ethiopian Veterinary Journal, 14, 71–82.

Alfredo, Z.L., 2015. The effect of education on smallholder pig farmers' knowledge, practices and pig productivity in the Angónia District, Mozambique.

Almeida, F.N., Htoo, J.K., Thomson, J. and Stein, H.H., 2014. Effects of heat treatment on the apparent and standardized ileal digestibility of amino acids in canola meal fed to growing pigs. Animal Feed Science and Technology, 187, pp.44-52.

Antwi, M., Seahlodi, P., 2011. Marketing constraints facing emerging small-scale pig farmers in Gauteng Province, South Africa. Journal of Human Ecology 36, 37–42. https://doi.org/10.1080/09709274.2011.11906415

Arega, S., Conraths, F., Ameni, G., 2013. Prevalence of tuberculosis in pigs slaughtered at two abattoirs in Ethiopia and molecular characterization of *Mycobacterium tuberculosis* isolated from tuberculous-like lesions in pigs. BMC Veterinary Research, 9, 97. https://doi.org/10.1186/1746-6148-9-97

Asar, E., Raheem, H., Daoud, J., 2018. Using dried leftover food as non-traditional feed for Muscovy duck diet. Assiut Veterinary Medical Journal 64, 107–114.

Bandino, E., Goddi, L., Mulas, M., Murgia, M.C., Soddu, M., Marucci, G., Pezzotti, P., Cabras, P.A., Pozio, E., 2015. *Trichinella britovi* from domestic to wild animals of Sardinia, Italy. Veterinary Parasitology, 212, 262–266. https://doi.org/10.1016/j.vetpar.2015.07.020

Banerjee, G.C., 2018. A Textbook of Animal Husbandry. Oxford & IBH Publishing Company Private, Limited.

Bartram, J., Carr, R., 2004. An introduction to emerging waterborne zoonoses and general control principles. Waterborne Zoonoses, 17.

Bonsu, K., Mugido, W., 2018. South African beef imports expected to remain flat in 2018. Global Agricultural Information Network, Pretoria, https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=South%20African%20Beef%20Imports%20Expected%20to%20Remain%20Flat%20in%202018_Pretoria_South%20Africa%20-%20Republic%20of_4-5-2018.pdf

Borah, S., Talukdar, R., Soren, S., Gogoi, J., Barman, K.C. and Tamuli, U.R., 2020. Participation of women in traditional pig farming in North bank plain zone of Assam. Indian Journal of Traditional Knowledge (IJTK), 19(2), pp.378-382.

Boumans, I.J., Schop, M., Bracke, M.B., de Boer, I.J., Gerrits, W.J. and Bokkers, E.A., 2022. Feeding food losses and waste to pigs and poultry: Implications for feed quality and production. Journal of Cleaner Production, 378, p.134623.

Boutsini, S., Papatsiros, V.G., Stougiou, D., Marucci, G., Liandris, E., Athanasiou, L.V., Papadoudis, A., Karagiozopoulos, E., Bisias, A., Pozio, E., 2014. Emerging *Trichinella britovi* infections in free ranging pigs of Greece. Veterinary Parasitology, 199, 278–282. https://doi.org/10.1016/j.vetpar.2013.10.007

Braae, U., Penrith, M.-L., Ngowi, H., Lekule, F., Johansen, M., 2016. Awareness concerning optimal pig production management and animal welfare among smallholder farmers in Tanzania. Animal Welfare, 25, 439–446. https://doi.org/10.7120/09627286.25.4.439

Braae, U.C., Saarnak, C.F.L., Mukaratirwa, S., Devleesschauwer, B., Magnussen, P., Johansen, M.V., 2015. *Taenia solium* taeniosis/cysticercosis and the co-distribution with schistosomiasis in Africa. Parasitic Vectors, 8, 323. https://doi.org/10.1186/s13071-015-0938-7

Bureau for Food and Agricultural Policy, 2021. Quantification of the South African Pork Value Chain: Phase 1. https://www.bfap.co.za/wp content/uploads/2023/04/Pork-Value-Chain-Study.pdf

Cabannes, Y., 2012. Financing urban agriculture. Environment and Urbanization, 24, 665–683. https://doi.org/10.1177/0956247812456126

Carter, N., Dewey, C., Mutua, F., de Lange, C., Grace, D., 2013. Average daily gain of local pigs on rural and peri-urban smallholder farms in two districts of Western Kenya. Tropical Animal Health and Production, 45. https://doi.org/10.1007/s11250-013-0395-2

Castrica, M., Tedesco, D.E., Panseri, S., Ferrazzi, G., Ventura, V., Frisio, D.G., Balzaretti, C.M., 2018. Pet food as the most concrete strategy for using food waste as feedstuff within the European context: A feasibility study. Sustainability, 10, 2035.

Chauhan, A., Patel, B.H.M., Maurya, R., Kumar, S., Shukla, S. and Kumar, S., 2016. Pig production system as a source of livelihood in Indian scenario: An overview. International Journal of Science and Environmental Technology, 5(4), pp.2089-96..

Chen, C., Gong, Y., Yang, L., 2022. Peasants and pork: The changing contribution of pig farming to rural livelihoods. Open Journal of Social Sciences, 10, 40–54. https://doi.org/10.4236/jss.2022.108003

Chenais, E., Lewerin, S.S., Boqvist, S., Ståhl, K., Alike, S., Nokorach, B., Emanuelson, U., 2019. Smallholders' perceptions on biosecurity and disease control in relation to African swine fever in an endemically infected area in Northern Uganda. BMC Veterinary Research, 15, 279. https://doi.org/10.1186/s12917-019-2005-7

Chiduwa, G., Chimonyo, M., Halimani, T.E., Chisambara, S.R., Dzama, K., 2008. Herd dynamics and contribution of indigenous pigs to the livelihoods of rural farmers in a semi-arid area of Zimbabwe. Tropical Animal Health and Production, 40, 125–136. https://doi.org/10.1007/s11250-007-9071-8

Chimonyo, M., Dzama, K. and Mapiye, C., 2010. Growth performance and carcass characteristics of indigenous Mukota pigs of Zimbabwe. Tropical Animal Health and Production, 42, pp.1001-1007.

Chittavong, M., Lindberg, J.E., Jansson, A., 2013. Feeding regime and management of local Lao pigs in Central Lao PDR. Tropical Animal Health and Production, 45, 149–155. https://doi.org/10.1007/s11250-012-0186-1

Cofie, O., van Veenhuizen, R., Drechsel, P., 2003. Contribution of urban and peri-urban agriculture to food security in Sub-Saharan Africa.

Costard, S., Wieland, B., de Glanville, W., Jori, F., Rowlands, R., Vosloo, W., Roger, F., Pfeiffer, D.U., Dixon, L.K., 2009. African swine fever: How can global spread be prevented? Philosophical Transactions of the Royal Society of London B Biological Sciences, 364, 2683–2696. https://doi.org/10.1098/rstb.2009.0098

Dame-Korevaar, A., Boumans, I.J., Antonis, A.F., van Klink, E. and de Olde, E.M., 2021. Microbial health hazards of recycling food waste as animal feed. Future Foods, 4, p.100062.

Damriyasa, I.M., Failing, K., Volmer, R., Zahner, H., Bauer, C., 2005. Prevalence, risk factors and economic importance of infestations with *Sarcoptes scabiei* and *Haematopinus suis* in sows of pig breeding farms in Hesse, Germany. Medical and Veterinary Entomology, 18, 361–7. https://doi.org/10.1111/j.0269-283X.2004.00520.x

Data, O.E.C.D., 2018. Meat consumption. The Organisation for Economic Co-operation and Development: Paris, France. Available at: https://data.oecd.org/agroutput/meat-consumption.htm. (Accessed: 28 August 2024).

Department of Agriculture, Fisheries and Forestry, 2021. Pork Market Value Chain Profile, South Africa. Available at: http://webapps1.daff.gov.za/AmisAdmin/upload/Pork%20Market%20Value%20Chain%20Profile%202021.pdf. (Accessed: 28 August 2024).

Department of Agriculture Land Reform and Rural Development, 2020. African swine

fever outbreak and surveillance update. 2020. Available at: http://sappo.org/PDF/other/ 2020/October/ASF-update-2020-10-23-1.pdf. (Accessed: 28 August 2024).

Department of Agriculture, Forestry and Fisheries, 1962. Animal Protection Act 71 of 1962. Government Gazette, No. 7706. Pretoria: Government Printer.

Dietze, K., 2011. Pigs for prosperity, Diversification booklet. FAO, Rome.

Dione, M., Masembe, C., Akol, J., Amia, W., Kungu, J., Lee, H.S., Wieland, B., 2018. The importance of on-farm biosecurity: Sero-prevalence and risk factors of bacterial and viral pathogens in smallholder pig systems in Uganda. Acta Tropica, 187, 214–221. https://doi.org/10.1016/j.actatropica.2018.06.025

Djimenou, D., Adoukonou-Sagbadja, H. and Koudande, D.O., 2023. Uses of local African pigs in food and traditional practices in Southern Benin. World Journal of Advanced Research and Reviews, 19(3), pp.925-935.

Doster, A.R., 1995. Skin diseases of swine. American Association of Swine Veterinarians, 3, 256–261.

EFSA Panel on Animal Health and Welfare (AHAW), Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin-Bastuji, B., Gonzales Rojas, J.L., Herskin, M. and Miranda Chueca, M.Á., 2021. African swine fever and outdoor farming of pigs. EFSA Journal, 19(6), p.e06639.

FAO/WB/OIE, 2009. Biosecurity refers to the necessary methods or measures implemented to protect both humans and animals from the introduction or spread of disease-causing agents.

Fasina, F.O., Agbaje, M., Ajani, F.L., Talabi, O.A., Lazarus, D.D., Gallardo, C., Thompson, P.N., Bastos, A.D.S., 2012. Risk factors for farm-level African swine fever infection in major pig-producing areas in Nigeria, 1997-2011. Previews in Veterinary Medicine, 107, 65–75. https://doi.org/10.1016/j.prevetmed.2012.05.011

Frendberg, L., 2012. Evaluation of physical properties of left-over food collected from hotels and restaurants as pig feed in urban and peri-urban areas of Kampala.

Fualefac, D.H., Raphae, K., Bime, M., Ndébi, G., Yemele, F., Zoli, P.A., Manjeli, Y., Téguia, A., Tchoumboué, J., 2014. Socioeconomic and technical characteristics of pig farming in the urban and peri-urban zone of Dschang-West region of Cameroon.

Gerber, P., Chilonda, P., Franceschini, G., Menzi, H., 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource Technology, 96, 263–276. https://doi.org/10.1016/j.biortech.2004.05.016

Geresu, M.A., Hailemariam, Z., Mamo, G., Tafa, M., Megersa, M., 2015. Prevalence and associated risk factors of major gastrointestinal parasites of pig slaughtered at Addis Ababa Abattoirs Enterprise, Ethiopia. Veterinary Science & Technology 6, 1.

Gong, Q.-L., Zhao, W.-X., Wang, Y.-C., Zong, Y., Wang, Q., Yang, Yang, Yang, Yi, Shi, K., Li, J.-M., Leng, X., Du, R., Zhao, Q., 2021. Prevalence of coccidia in domestic pigs in China between 1980 and 2019: A systematic review and meta-analysis. Parasitic Vectors 14, 248. https://doi.org/10.1186/s13071-021-04611-x

Graefe, S., Schlecht, E., Buerkert, A., 2008. Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. Outlooks in Agricukture, 37, 47–56. https://doi.org/10.5367/000000008783883564

Hale, O.M., Stewart, T.B., 1979. Influence of an experimental infection of *Trichuris suis* on performance of pigs. Journal of Animal Science, 49, 1000–1005.

Halimani, T.E., Muchadeyi, F.C., Chimonyo, M., Dzama, K., 2012. Some insights into the phenotypic and genetic diversity of indigenous pigs in southern Africa. South African Journal of Animal Science, 42, 507–510.

Ham, Y.K., Song, D.H. and Kim, H.W., 2022. Effects of toxic heavy metal salts on oxidative quality deterioration in ground pork model during aerobic display storage. *Antioxidants*, *11*(7), p.1310.

Hlongwane, N.L., Hadebe, K., Soma, P., Dzomba, E.F. and Muchadeyi, F.C., 2020. Genome wide assessment of genetic variation and population distinctiveness of the pig family in South Africa. Frontiers in Genetics, 11, p.344.

Holness, D.H., 1991. The tropical agriculturist. Pigs.

Hossain, M., Chakma, S., Khatun, M., Hasanuzzaman, M., Miah, M., Biswas, M., 2012. Production systems of swine in the rural areas of Rangamati and Khagrachari districts of Bangladesh. Bangladeshi Journal of Animal Science, 40, 28–33. https://doi.org/10.3329/bjas.v40i1-2.10787

International Federation for Animal Health, 2013. Emerging and re-emerging animal diseases. IFAH Annual Report. Available at:

https://healthforanimals.org/resources/publications/publications/ifah-annual-report-2013/ifah-annual-report-2013-2/. (Accessed: 03 March 2024).

Janse van Rensburg, L., Van Heerden, J., Penrith, M.-L., Heath, L.E., Rametse, T., Etter, E.M.C., 2020. Investigation of African swine fever outbreaks in pigs outside the controlled areas of South Africa, 2012-2017. Journal of the South African Veterinary Association, 91, e1–e9. https://doi.org/10.4102/jsava.v91i0.1997

Jedrejek, D., Lević, J., Wallace, J. and Oleszek, W., 2016. Animal by-products for feed: Characteristics, European regulatory framework, and potential impacts on human and animal health and the environment.

Jones, B.A., Grace, D., Kock, R., Alonso, S., Rushton, J., Said, M.Y., McKeever, D., Mutua, F., Young, J., McDermott, J. and Pfeiffer, D.U., 2013. Zoonosis emergence linked to agricultural intensification and environmental change. Proceedings of the National Academy of Sciences, 110(21), pp.8399-8404.

Jufare, A., Awol, N., Tadesse, F., Tsegaye, Y., Hadush, B., 2015. Parasites of pigs in two farms with poor husbandry practices in Bishoftu, Ethiopia. Onderstepoort Journal of Veterinary Research, 82, 5 pages. https://doi.org/10.4102/ojvr.v82i1.839

Jurado, C., Martínez-Avilés, M., De La Torre, A., Štukelj, M., de Carvalho Ferreira, H.C., Cerioli, M., Sánchez-Vizcaíno, J.M. and Bellini, S., 2018. Relevant measures to prevent the spread of African swine fever in the European Union domestic pig sector. Frontiers in Veterinary Science, 5, p.77.

Kadirvel, G., Devi, Y.S., Naskar, S., Bujarbaruah, K.M., Khargariah, G., Banik, S., Singh, N.S. and Gonmei, C., 2023. Performance of crossbred pigs with indigenous and Hampshire inheritance under a smallholder production system in the Eastern Himalayan hill region. Frontiers in genetics, 14, p.1042554.

Kagira, J.M., Kanyari, P.N., Githigia, S.M., Maingi, N., Ng'ang'a, J.C., Gachohi, J.M., 2012. Risk factors associated with occurrence of nematodes in free range pigs in Busia District, Kenya. Tropical Animal Health and Production, 44, 657–664. https://doi.org/10.1007/s11250-011-9951-9

Kagira, J.M., Kanyari, P.N., Maingi, N., Githigia, S.M., Ng′ang′a, C., Gachohi, J., 2013. Relationship between the prevalence of ectoparasites and associated risk factors in free-range pigs in Kenya. International Scholarly Research Notices, 2013, 650890. https://doi.org/10.1155/2013/650890

Kagira, J.M., Kanyari, P.W.N., 2010. Questionnaire survey on urban and peri-urban livestock farming practices and disease control in Kisumu municipality, Kenya. Journal of the South African Veterinary Association, 81, 82–86. https://doi.org/10.4102/jsava.v81i2.110

Kagira, J.M., Kanyari, P.W.N., Maingi, N., Githigia, S.M., Ng'ang'a, J.C., Karuga, J.W., 2010a. Characteristics of the smallholder free-range pig production system in western Kenya. Tropical Animal Health and Production, 42, 865–873. https://doi.org/10.1007/s11250-009-9500-y

Kambashi, B., Picron, P., Boudry, C., Théwis, A., Kiatoko, H., Bindelle, J., 2014. Smallholder pig production systems along a periurban-rural gradient in the Western provinces of the Democratic Republic of the Congo. Journal of Agriculture and Rural Development in the Tropics and Subtropics.

Kanengoni, A.T., Chimonyo, M., Ndimba, B.K., Dzama, K., 2015. Potential of using maize cobs in pig diets - A Review. Asian-Australasian Journal of Animal Science, 28, 1669–1679. https://doi.org/10.5713/ajas.15.0053

Katongole, C.B., Nambi-Kasozi, J., Lumu, R., Bareeba, F., Presto, M., Ivarsson, E., Lindberg, J.E., 2012. Strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 113, 165–174.

Khapayi, M., Celliers, P.R., 2016. Factors limiting and preventing emerging farmers to progress to commercial agricultural farming in the King William's Town area of the Eastern Cape Province, South Africa. South African Journal of Agricultural Extension, 44, 25–41. https://doi.org/10.17159/2413-3221/2016/v44n1a374

Kithinji, K.R., Kanui, T.I., Ndathi, A.J., Mwobobia, R.M., 2017. Characterization of pig production systems in Embu west sub county, Embu County, Kenya.

Koketsu, Y., Takenobu, S., Nakamura, R., 2006. Preweaning mortality risks and recorded causes of death associated with production factors in swine breeding herds in Japan. The Journal of Veterinary and Medical Sciences / the Japanese Society of Veterinary Science, 68, 821–6. https://doi.org/10.1292/jvms.68.821

Krecek, R.C., Maingi, N., 2004. Comparison of two techniques used for the recovery of third-stage strongylid nematode larvae from herbage. Veterinary Parasitology, 122, 233–244. https://doi.org/10.1016/j.vetpar.2004.04.009

Laddomada, A., Rolesu, S., Loi, F., Cappai, S., Oggiano, A., Madrau, M.P., Sanna, M.L., Pilo, G., Bandino, E., Brundu, D., Cherchi, S., Masala, S., Marongiu, D., Bitti, G., Desini, P., Floris, V., Mundula, L., Carboni, G., Pittau, M., Feliziani, F., Sanchez-Vizcaino, J.M., Jurado, C., Guberti, V., Chessa, M., Muzzeddu, M., Sardo, D., Borrello, S., Mulas, D., Salis, G., Zinzula, P., Piredda, S., De Martini, A., Sgarangella, F., 2019. Surveillance and control of African Swine Fever in free-ranging pigs in Sardinia. Transboundary and Emerging Diseases, 66, 1114–1119. https://doi.org/10.1111/tbed.13138

Lañada, E.B., Lee, J.-A.L.M., More, S.J., Cotiw-an, B.S., Taveros, A.A., 2005. A longitudinal study of sows and boars raised by smallholder farmers in the Philippines. Preventive Veterinary Medicine, 70, 95–113. https://doi.org/10.1016/j.prevetmed.2005.02.015

Lee, J.-A.L.M., Lañada, E.B., More, S.J., Cotiw-an, B.S., Taveros, A.A., 2005. A longitudinal study of growing pigs raised by smallholder farmers in the Philippines. Preview of Veterinary Medicine, 70, 75–93. https://doi.org/10.1016/j.prevetmed.2005.02.016

Lee, S., Alkathiri, B., Kwak, D., Lee, S.M., Lee, W.K., Byun, J.W. and Lee, S.H., 2022. Distribution of gastrointestinal parasitic infection in domestic pigs in the Republic of Korea: Nationwide survey from 2020–2021. The Korean Journal of Parasitology, 60(3), p.207.

Lekule, F.P., Kyvsgaard, N.C., 2003. Improving pig husbandry in tropical resource-poor communities and its potential to reduce risk of porcine cysticercosis. Acta Tropica, 87, 111–117. https://doi.org/10.1016/s0001-706x(03)00026-3

Lemke, U., Kaufmann, B., Thuy, L.T., Emrich, K., Zárate, A.V., 2007. Evaluation of biological and economic efficiency of smallholder pig production systems in North Vietnam. Tropical Animal Health and Production, 39, 237–254. https://doi.org/10.1007/s11250-007-9001-9

Luciano, A., Tretola, M., Ottoboni, M., Baldi, A., Cattaneo, D. and Pinotti, L., 2020. Potentials and challenges of former food products (food leftover) as alternative feed ingredients. Animals, 10(1), p.125.

Madzimure, J., Bovula, N., Ngorora, D.G., Tada, O., Kagande, S., Bakare, A., Chimonyo, M., 2014. Market opportunities and constraints confronting resource-poor pig farmers in South Africa's Eastern Cape Province. Journal of Industrial Distribution & Business, 5. https://doi.org/10.13106/jidb.2014.vol5.no2.29

Madzimure, J., Chimonyo, M., Zander, K.K., Dzama, K., 2013. Potential for using indigenous pigs in subsistence-oriented and market-oriented small-scale farming systems of Southern Africa. Tropical Animal Health and Produbtion, 45, 135–142. https://doi.org/10.1007/s11250-012-0184-3

Matabane, M.B., Nethenzheni, P., Thomas, R., Netshirovha, T.R., Norris, D., Nephawe, K.A., Nedambale, T.L., 2015. Status of the smallholder pig farming sector in Gauteng Province of South Africa. Rural Development, 8.

Mazari-Hiriart, M., Ponce-de-León, S., López-Vidal, Y., Islas-Macías, P., Amieva-Fernández, R.I., Quiñones-Falconi, F., 2008. Microbiological implications of periurban agriculture and water reuse in Mexico City. PLoS One, 3, e2305. https://doi.org/10.1371/journal.pone.0002305

Mekuriaw, Y., Asmare, B., 2014. Assessment of pig production and constraints in Mecha District, Amhara Region, Northwestern Ethiopia. Advances in Agriculture, 2014, 1–5. https://doi.org/10.1155/2014/329254

Mhoma, J.R., Kanyari, P.W.N., Kagira, J.M., 2012. The prevalence of ecto and endoparasites in pigs in urban and peri-urban areas of Mwanza City, Tanzania. Huria: Journal of the Open University of Tanzania, 10, 34–42.

Miao, Z.H., Glatz, P.C., Ru, Y.J., 2005. Free-range poultry production - A review. Asian-Australasian Journal of Animal Sciences, 18, 113–132.

Miao, Z.H., Glatz, P.C., Ru, Y.J., 2004. Review of production, husbandry and sustainability of free-range pig production systems. Asian-Australasian Journal of Animal Sciences, 17, 1615–1634.

Mohakud, S.S., Hazarika, R.A., Sonowal, S., Bora, D.P., Talukdar, A., Tamuly, S., Lindahl, J.F., 2020. The extent and structure of pig rearing system in urban and peri-urban areas of Guwahati. Infection Ecology & Epidemiology, 10, 1711576. https://doi.org/10.1080/20008686.2020.1711576

Mokoele, J.M., Spencer, B.T., van Leengoed, L.A.M.G., Fasina, F.O., 2014. Efficiency indices and indicators of poor performance among emerging small-

scale pig farmers in the Limpopo Province, South Africa. Onderstepoort Journal of Veterinary Research, 81. https://doi.org/10.4102/ojvr.v81i1.774

Molotsi, A.H., Cupido, M. and Hoffman, L.C., 2021. Characterization of smallholder pig production systems in the Western Cape, South Africa. Tropical Animal Health and Production, 53(2), p.325.

Montsho, T., Moreki, J.C., 2012. Challenges in commercial pig production in Botswana 8.

Motsa'a, J.S., Defang, H.F., Hako, T.B.A., Ojong, E.T., Mube, K.H., Nguekem, C.L., 2021. Socioeconomic and productive characteristics of indigenous pig farming in Cameroon. Rural Development, 14.

Mthiyane, D.B., Wissink, H. and Chiwawa, N., 2022. The impact of rural–urban migration in South Africa: A case of KwaDukuza municipality. *Journal of Local Government Research and Innovation*, *3*, p.56.

Mugido, W., 2017. The South African pork market. Pretoria: USDA Foreign Agricultural Service. Retrieved from USDA Foreign Agricultural Service: apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=The%20South%20African%20pork%20market%20_Pretoria_ South%20Africa%20-%20Republic%20of_9-5-2017.pdf

Muhanguzi, D., Lutwama, V., Mwiine, F., 2012. Factors that influence pig production in Central Uganda - Case study of Nangabo Sub-County, Wakiso district. Veterinary World, 5, 346. https://doi.org/10.5455/vetworld.2012.346-351

Munzhelele, P., 2015. Evaluation of the production systems and constraints of smallholder pig farming in three agro-ecological zones of Mpumalanga province, South Africa (Masters Dissertation).

Munzhelele, P., Oduniyi, O.S., Scheltens, M.L., Antwi, M., Christian, M., Fasina, F.O., 2021. Determinants of market choice and strategies adopted by small-scale pig producers in redline areas of Mpumalanga Province, South Africa: A Fractional Outcome-Tobit Model Approach. South Africa 48.

Munzhelele, P., Oguttu, J., Fasanmi, O.G., Fasina, F.O., 2017. Production constraints of smallholder pig farms in agro-ecological zones of Mpumalanga, South Africa. Tropical Animal Health and Production, 49, 63–69. https://doi.org/10.1007/s11250-016-1158-7

Munzhelele, P., Oguttu, J.W., Fasina, F.O., 2016. Is a 10-sow unit economically sustainable? A profitability assessment of productivity amongst small-holder

pig farmers, Mpumalanga, South Africa. Onderstepoort Journal of Veterinary Research, 83, 1–11. https://doi.org/10.4102/ojvr.v83i1.1011

Munzhelele, P., Sibeko, N.P.S., Oguttu, J.W., Mbajiorgu, C.A., Fasina, F.O., 2024. Parasites burden in peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga Province, South Africa. Journal of the South African Veterinary Association, 95, 55–66. https://doi.org/10.36303/JSAVA.601

Mutua, F.K., Dewey, C., Arimi, S., Ogara, W., Levy, M., Schelling, E., 2012. A description of local pig feeding systems in village smallholder farms of Western Kenya. Tropical Animal Health and Production, 44, 1157–1162. https://doi.org/10.1007/s11250-011-0052-6

Mwanjali, G., Kihamia, C., Kakoko, D.V.C., Lekule, F., Ngowi, H., Johansen, M.V., Thamsborg, S.M., Willingham III, A.L., 2013. Prevalence and risk factors associated with human *Taenia solium* infections in Mbozi District, Mbeya Region, Tanzania. PLoS One Neglected Tropical Diseases, 7, e2102.

Mwape, K.E., Phiri, I.K., Praet, N., Muma, J.B., Zulu, G., Van Den Bossche, P., De Deken, R., Speybroeck, N., Dorny, P., Gabriël, S., 2012. *Taenia solium* infections in a rural area of Eastern Zambia-A community based study. PLoS Neglected Tropical Diseases, 6, e1594. https://doi.org/10.1371/journal.pntd.0001594

Nath, B.G., Pathak, P.K., Ngachan, S.V., Tripathi, A.K., Mohanty, A.K., 2013. Characterization of smallholder pig production system: Productive and reproductive performances of local and crossbred pigs in Sikkim Himalayan region. Tropical Animal Health and Production, 45, 1513–1518. https://doi.org/10.1007/s11250-013-0391-6

Nsoso, S.J., Mosala, K.P., Ndebele, R.T., 2000. The prevalence of internal and external parasites in pigs of different ages and sexes in Southeast District, Botswana.

Nwafor, C.C., Keshinro, O.S., Abudu, E.K., 2015. A histopathological study of prostate lesions in Lagos, Nigeria: A private practice experience. Nigerian Medical Journal, 56, 338. https://doi.org/10.4103/0300-1652.170388

Oba, P., Wieland, B., Mwiine, F.N., Erume, J., Gertzell, E., Jacobson, M. and Dione, M.M., 2020. Status and gaps of research on respiratory disease pathogens of swine in Africa. Porcine Health Management, 6(1), p.5.

Odo, G.E., Agwu, E.J., Ossai, N.I.K., Ezea, C.O., Nwokolo, E.C., Eneje, V., 2016. A survey of ectoparasites of local pigs, *Sus scrofa domesticus* at Emene Town area in Enugu State. Academic Journal of Biotechnology, 4, 126–137.

Okello, E., Collins, A., De Greve, H., 2015. Analysis of performance, management practices and challenges to intensive pig farming in peri-urban Kampala, Uganda. International Journal of Livestock Production, 6, 1–7. https://doi.org/10.5897/IJLP2014.0223

Olson, M., Guselle, N., 2000. Are pig parasites a human health risk. Advances in Pork Production, 11.

Olasupo, O., 2025. Africa's pig industry: Past and present status [www Document]. URL https://www.pig333.com/articles/africa's-pig-industry-past-and-present-status_21253/ (accessed 6.29.25).

Ouma, E., Dione, M., Lule, P., Rosel, K., Pezo, D., 2013. Characterization of smallholder pig production systems in Uganda: Constraints and opportunities for engaging with market systems. 2013 Fourth International Conference, September 22-25, 2013, Hammamet, Tunisia, 2013.

Papatsiros, V., 2011. Impact of animal health management on organic pig farming in Greece. Biotechnology in Animal Husbandry, 2011, vol. 27(1), 115-125. Biotechnology in Animal Husbandry.

Papatsiros, V.G., Tassis, P.D., Christodoulopoulos, G., Boutsini, S., Tsirigotakis, G., Tzika, E.D., 2012. Health and production of Greek organic pig farming: Current situation and perspectives. Journal of the Hellenic Veterinary Medical Society, 63, 37–44. https://doi.org/10.12681/jhvms.15396

Payne, A., Ogweng, P., Ståhl, K., Masembe, C. and Jori, F., 2021. Spatial-temporal movements of free ranging pigs at the wildlife-livestock interface of Murchison Falls National Park, Uganda: Potential of disease control at a local scale. Frontiers in Veterinary Science, 8, p.689377.

Payne, K., O'Bryan, C.A., Marcy, J.A. and Crandall, P.G., 2023. Detection and prevention of foreign material in food: A review. *Heliyon*, *9*(9).

Pettersson, E., Sjölund, M., Dórea, F.C., Lind, E.O., Grandi, G., Jacobson, M., Höglund, J. and Wallgren, P., 2021. Gastrointestinal parasites in Swedish pigs: Prevalence and associated risk factors for infection in herds where animal welfare standards are improved. Veterinary Parasitology, 295, p.109459.

Permin, A., Yelifari, L., Bloch, P., Steenhard, N., Hansen, N.P., Nansen, P., 1999. Parasites in cross-bred pigs in the Upper East region of Ghana. Veterinary Parasitology, 87, 63–71. https://doi.org/10.1016/s0304-4017(99)00159-4

Petrus, N., Mpofu, I., Schneider, M.B., Nepembe, M., 2011. The constraints and potentials of pig production among communal farmers in Etayi Constituency of Namibia. Livestock Research for Rural Development, 23.

Phengsavanh, P., Ogle, B., Stur, W., Frankow-Lindberg, B.E., Lindberg, J.E., 2011. Smallholder pig rearing systems in Northern Lao PDR. Asian-Australasian Journal of Animal Sciences, 24, 867–874. https://doi.org/10.5713/ajas.2011.10289

Phengsavanh, P., Ogle, B., Stür, W., Frankow-Lindberg, B.E., Lindberg, J.E., 2010. Feeding and performance of pigs in smallholder production systems in Northern Lao PDR. Tropical Animal Health and Production, 42, 1627–1633. https://doi.org/10.1007/s11250-010-9612-4

Phiri, I.K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., Lubega, G.W., Kassuku, A., Michael, L., Siziya, S., Krecek, R.C., Noormahomed, E., Vilhena, M., Dorny, P., Willingham, A.L., 2003. The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. Acta Tropica, 87, 13–23. https://doi.org/10.1016/s0001-706x(03)00051-2

Pig333., 2024. Ranking of pork producing, exporting, importing, and consuming countries in 2024. Available at: https://www.pig333.com/latest_swine_news/ranking-of-pork-producing-exporting-importing-consuming-.countries_19810/#:~:text=With%20a%20share%20of%20over%2050%25%2C%20China%20would,positions%20with%20shares%20of%2015.7%20and%208.7%25%2C%20respectively. (Accessed: 16 February 2024).

Pondja, A., Neves, L., Mlangwa, J., Afonso, S., Fafetine, J., Iii, A.L.W., Thamsborg, S.M., Johansen, M.V., 2010. Prevalence and risk factors of porcine cysticercosis in Angónia District, Mozambique. PLoS Neglected Tropical Diseases, 4, e594. https://doi.org/10.1371/journal.pntd.0000594

Praet, N., Kanobana, K., Kabwe, C., Maketa, V., Lukanu, P., Lutumba, P., Polman, K., Matondo, P., Speybroeck, N., Dorny, P., Sumbu, J., 2010. *Taenia solium*

cysticercosis in the Democratic Republic of Congo: How does pork trade affect the transmission of the parasite? PLoS Neglected Tropical Diseases, 4, e817. https://doi.org/10.1371/journal.pntd.0000817

Radhakrishnan, M., Saseendran, P.C., Anil, K.S., George, S., Usha, A.P., Kannan, A., Muhammad Aslam, M.K., 2018. Analysis of waste management system followed in pig farms in Kerala. Animal Science Reporter, 11.

Rametse, T., Janse van Rensburg, L., Van Heerden, J., Heath, L.E., Etter, E.M. and Penrith, M.L., 2020. Investigation of African swine fever outbreaks in pigs outside the controlled areas of South Africa, 2012–2017. Journal of the South African Veterinary Association, 91(1), pp.1-9.

Ritchie, H., Rosado, P., Roser, M., 2023. Meat and dairy production. Our World in Data [internet]. URL https://ourworldindata.org/meat-production. (Accessed 02.03.2024).

Roesel, K., Ejobi, F., Dione, M., Pezo, D., Ouma, E., Kungu, J., Clausen, P.-H., Grace, D., 2019. Knowledge, attitudes and practices of pork consumers in Uganda. Global Food Security, 20, 26–36. https://doi.org/10.1016/j.gfs.2018.12.001

Sanchez Botija, C., Badiola, C., 1966. [Presence of the African swine pest virus in Haematopinus suis]. Bull Off Int Epizoot, 66, 699–705.

Sather, A.P., Jones, S.D.M., Schaefer, A.L., Colyn, J., Robertson, W.M., 1997. Feedlot performance, carcass composition and meat quality of free-range reared pigs. Canadian Journal of Animal Science, 77, 225–232. https://doi.org/10.4141/A96-093

Shankar, B.P., Madhusudhan, Harish, D.B., 2009. Pre-weaning mortality in pig-causes and management. Veterinary World, 2, 236–239.

Sowemimo, O.A., Asaolu, S.O., Adegoke, F.O. and Ayanniyi, O.O., 2012. Epidemiological survey of gastrointestinal parasites of pigs in Ibadan, Southwest Nigeria. Journal of Public Health and Epidemiology, 4(10), pp.294-298.

Stats SA, 2023. November 2023 | Statistics South Africa. URL https://www.statssa.gov.za/?p=16831 (accessed 3.18.24).

Stenmarck, Å., Jensen, C., Quested, T. and Moates, G., 2016. Estimates of European food waste levels.

Stewart, T.B., Hale, O.M., 1988. Losses to internal parasites in swine production. J Animal Science, 66, 1548–1554. https://doi.org/10.2527/jas1988.6661548x

Ström, G., Andersson Djurfeldt, A., Boqvist, S., Albihn, A., Sokerya, S., San, S., Davun, H., Magnusson, U., 2017. Urban and peri-urban family-based pig-keeping in Cambodia: Characteristics, management and perceived benefits and constraints. PLoS One, 12, e0182247. https://doi.org/10.1371/journal.pone.0182247

Sur, J.H., 2019. How far can African swine fever spread?. Journal of Veterinary Science, 20(4).

Tekle, T., Tesfay, A., Kifleyohannes, T., 2013. Smallholder pig production and its constraints in Mekelle and southern zone of Tigray region, north Ethiopia. Livestock Research for Rural Development, 25, 1–10.

Thanasuwan, S., Piratae, S., Thaowandee, K. and Amporn, C., 2024. Prevalence and diversity of gastrointestinal parasites on pig farms in Kalasin Province, Thailand. Veterinary World, 17(2), p.273.

Thomas, L.F., de Glanville, W.A., Cook, E.A., Fèvre, E.M., 2013. The spatial ecology of free-ranging domestic pigs (Sus scrofa) in western Kenya. BMC Veterinary Research, 9, 46. https://doi.org/10.1186/1746-6148-9-46

Thys, S., Mwape, K.E., Lefèvre, P., Dorny, P., Phiri, A.M., Marcotty, T., Phiri, I.K., Gabriël, S., 2016. Why pigs are free-roaming: Communities' perceptions, knowledge and practices regarding pig management and taeniosis/cysticercosis in a *Taenia solium* endemic rural area in Eastern Zambia. Veterinary Parasitology, 225, 33–42. https://doi.org/10.1016/j.vetpar.2016.05.029

Tolosa, J., Rodríguez-Carrasco, Y., Ruiz, M.J., Vila-Donat, P., 2021. Multi-mycotoxin occurrence in feed, metabolism and carry-over to animal-derived food products: A review. Food and Chemical Toxicology, 158, 112661. https://doi.org/10.1016/j.fct.2021.112661

Tomass, Z., Imam, E., Kifleyohannes, T., Tekle, Y., Weldu, K., 2013. Prevalence of gastrointestinal parasites and Cryptosporidium species in extensively managed pigs in Mekelle and urban areas of southern zone of Tigray region, Northern Ethiopia. Veterinary World, 6, 433. https://doi.org/10.5455/vetworld.2013.433-439

Trevisan, C., Mkupasi, E.M., Ngowi, H.A., Forkman, B. and Johansen, M.V., 2016. Severe seizures in pigs naturally infected with *Taenia solium* in Tanzania. Veterinary Parasitology, 220, pp.67-71.

Umeh, S., Ike, E., Gbughemobi, B., 2018. Analysis of the environmental effect of pig production in Okigwe Local Government Area of Imo State, Nigeria. https://doi.org/10.13140/RG.2.2.19327.46248

Vogt, D., Swartz, H.A. and Massey, J., 2018. Inbreeding: Its meaning, uses and effects on farm animals.

Vosloo, W., Boshoff, K., Dwarka, R. and Bastos, A., 2002. The possible role that buffalo played in the recent outbreaks of foot-and-mouth disease in South Africa. Annals of the New York Academy of Sciences, 969(1), pp.187-190.

Wabacha, J.K., Maribei, J.M., Mulei, C.M., Kyule, M.N., Zessin, K.H., Oluoch-Kosura, W., 2004. Characterisation of smallholder pig production in Kikuyu Division, central Kenya. Preview of Veterinary Medicine, 63, 183–195. https://doi.org/10.1016/j.prevetmed.2004.02.007

Wadhwa, M., Bakshi, M., Makkar, H., 2013. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products.

Walt, J. van der, 2021. Free-range pigs: lessons learnt on the way to commercial success. Farmer's Weekly. URL https://www.farmersweekly.co.za/animals/pigs/free-range-pigs-lessons-learnt-on-the-way-to-commercial-success/ (accessed 6.19.25).

Webster J., 2016. Animal Welfare: Freedoms, Dominions and "A Life Worth Living". Animals: an open access journal from MDPI, 6(6), 35. https://doi.org/10.3390/ani6060035

Weka, R., Bwala, D., Adedeji, Y., Ifende, I., Davou, A., Ogo, N. and Luka, P., 2021. Tracing the domestic pigs in Africa. In Tracing the domestic pig. IntechOpen.

Wu, N., Abril, C., Thomann, A., Grosclaude, E., Doherr, M.G., Boujon, P. and Ryser-Degiorgis, M.P., 2012. Risk factors for contacts between wild boar and outdoor pigs in Switzerland and investigations on potential *Brucella suis* spill-over. BMC Veterinary Research, 8, pp.1-12.

Zhai, S.L., Wen-Kang, W., Ming-Fei, S., Lv, D.H. and Zhi-Hong, X., 2019. African swine fever spread in China. The Veterinary Record, 184(18), p.559.

Zu Ermgassen, E.K.H.J., Kelly, M., Bladon, E., Salemdeeb, R., Balmford, A., 2018. Support amongst UK pig farmers and agricultural stakeholders for the use of food losses in animal feed. PLoS One 13, e0196288. https://doi.org/10.1371/journal.pone.0196288

CHAPTER THREE

PARASITES BURDEN IN PERI-URBAN FREE-ROAMING PIGS IN GERT SIBANDE DISTRICT MUNICIPALITY, MPUMALANGA PROVINCE, SOUTH AFRICA

ABSTRACT

Background: Parasite infections, unlike regulated animal diseases, do not often receive attention. Yet parasites are major sources of financial losses in pig enterprises, particularly in subsistence and small-scale pig production systems.

Objective: To identify and quantify the prevalence of ecto- and endoparasites among peri-urban free-roaming pigs (FRP) in Gert Sibande District Municipality (GSDM), Mpumalanga.

Method: Pig owners were identified using the snowball sampling method since no sampling frame for FRP farmers exists. Stratified sampling was used to select pigs for sampling for ecto- and endoparasites. A form was used to record the observations. Pairwise correlation analysis was performed using Stata 15.0. The software SPSS V28.0 was used to perform the chi-square test (X^2) to assess the distribution of parasites in different age groups, and the prevalence of parasites in different age groups of pigs was assessed using multi-response crosstabs. Multivariate analysis of variance (MANOVA) was used to estimate the marginal mean of parasites according to municipality. Statistical significance was assessed at $\alpha \leq 0.05$.

Results: Over 90% (91.2%) of the pigs examined were infested with at least one parasite, including *Haematopinus suis, Sarcoptes scabiei*, *Ascaris suum*, *Fasciola hepatica*, *Trichuris suis*, *Strongylids*, *Coccidia* spp., *Moniezia expansa*, and *Siphonaptera* spp. The correlation between *Ascaris suum* and body condition was weak but statistically significant ($r = 0.24$; $p < 0.05$). *Sarcoptes scabiei* was commonly isolated in all age categories, with the highest prevalence observed in pigs aged ≥ 12 months (41.6%) and ≤ 4 months (28.0%). The municipalities exhibiting a significant prevalence of pigs positive for *Ascaris suum* were Mkhondo (41.1%) and Govan Mbeki (30.8%).

Conclusion*:* Policy makers, animal researchers and veterinary services must focus on developing policies, risk communication and community engagement materials,

which target pig farmers in peri-urban areas such as Gert Sibande District Municipality, Mpumalanga Province.

Keywords: gastro-intestinal parasites, ectoparasites, free-roaming pigs, disease, and zoonosis

3.1. INTRODUCTION

Pig farming has been recognised as a means of alleviating poverty, creating jobs, ensuring food security, providing a source of protein, and contributing to national GDPs (Adebisi, 2008; Nonga & Paulo, 2015; Odo *et al*., 2016; Nwafor *et al*., 2019). These recognitions are based on the fact that pigs have distinguishing traits, including rapid growth, excellent feed conversion, ease of housing and slaughter, need for smaller land area per unit, high fecundity, high protein content (pork), and ease of adaptation to diverse climatic situations. Despite the pig's outstanding performance, the pig industry is constrained by multiple yet overlooked challenges.

For many years, the South African pig industry has experienced numerous production-related and animal health issues with severe economic implications. Certain pig production systems used in the industry, particularly the extensive pig production system; act as catalysts for disease outbreaks. Such outbreaks may include, but are not limited to; classical swine fever (CSF), African swine fever (ASF) and salmonellosis. In the peri-urban areas of Mpumalanga Province (MP), including near human dwellings, open areas, along streams, and around garbage dumps, numerous pigs can be spotted roaming freely. In addition, a previous study conducted in MP confirmed that numerous pigs were slaughtered at home without the ante-mortem inspection by authorised veterinary services (Munzhelele, 2015; Munzhelele *et al*., 2017; DCGTA, 2020). This situation portends high food safety and health risks to both humans and animals from the informal pig sector.

Parasitic diseases are commonly disregarded in smallholder pig farming, largely because unlike some rapidly spreading infectious diseases, parasitic diseases hardly cause enormous mortality. Furthermore, parasite infections, unlike regulated animal

diseases, do not receive much attention in South Africa. Moreover, a high burden of parasite infestation can have severe negative economic impacts on the pig industry. Ecto- and endoparasites are major limitations to financial well-being and productivity in smallholder pig operation. In fact, previous research has shown that parasites have an ultimate effect on productivity and production outputs such as poor growth rate, litter size, low birth weight, reduced weight gain, poor feed conversion efficiency, decreased appetite, poor fertility, emaciation in pigs, condemnation of damaged organs after slaughter, respiratory distress, and high mortality and may lead to significantly high treatment costs. In addition, some parasites from pigs have zoonotic potential (Nsoso *et al*., 2000; Ngowi *et al*., 2004; Stewart and Hoyt, 2006; Sowemimo *et al*., 2012; Kagira *et al*., 2012; Wilson and Swai, 2014; Kumsa and Kifle, 2014; Nonga and Paulo, 2015; Nwafor *et al*., 2019).

Parasitic infections and infestations of the host may occur through contaminated feeds, water, pasture, and direct contact with pigs from infected areas, rearing pigs in filthy conditions, and poor farm management (Soulsby, 1982; Damriyasa *et al*., 2004; Kagira *et al*., 2013; Nsoso *et al*., 2006; Tamboura *et al*., 2006). The lack of biosecurity and parasite control in small-scale farm settings exacerbates the situation in pig farming (Munzhelele, 2015; Munzhelele *et al*., 2021). Furthermore, poor management, insufficient nutrition, a free-roaming pig (FRP) rearing system, and poor herd health, all of which predominate the smallholder farming system, are the leading causes of parasite endemicity in pig farming.

To date, the occurrence or prevalence of ecto- and endoparasitism among FRP in the Gert Sibande District Municipality (GSDM)'s peri-urban areas (PUA) are unknown and hence require investigation. The purpose of this study was to identify and quantify the prevalence of ecto- and endoparasites in free roaming pigs in the peri-urban areas of GSDM, Mpumalanga Province, and to assess the impact of parasitic load on the performance of FRP in the PUA of Mpumalanga Province.

3.2. MATERIALS AND METHODS

3.2.1. Study area

South Africa has nine provinces with a total area of 1 221 037 km^2. Mpumalanga is South Africa's second-smallest province after Gauteng, occupying approximately 79 494 km^2. Mpumalanga Province has three district municipalities, including: Gert Sibande, Nkangala and Ehlanzeni. The district shares boundaries with three provinces, including Free State, Gauteng and Kwazulu Natal and one international country of eSwatini. The current study was conducted in the Gert Sibande District Municipality (GSDM). The GSDM (26.5471^{o}S, 29.9741^{o}E) is the largest district in MP covering 31 845,9 km^2 (41% of the total land area of Mpumalanga). It consists of seven municipalities, including Msukaligwa, Govan Mbeki, Dipaliseng, Lekwa, Pixley ka Seme, Mkhondo and Chief Albert Luthuli (Figure 3.1).

Mining (26%) is the largest economic sector in GSDM, followed by manufacturing (1 8%), community services (15%), and agriculture with only 3%. The district is hampered by high poverty rates (46.5%) and large unemployment (38.4%) (COGTA, 2020).

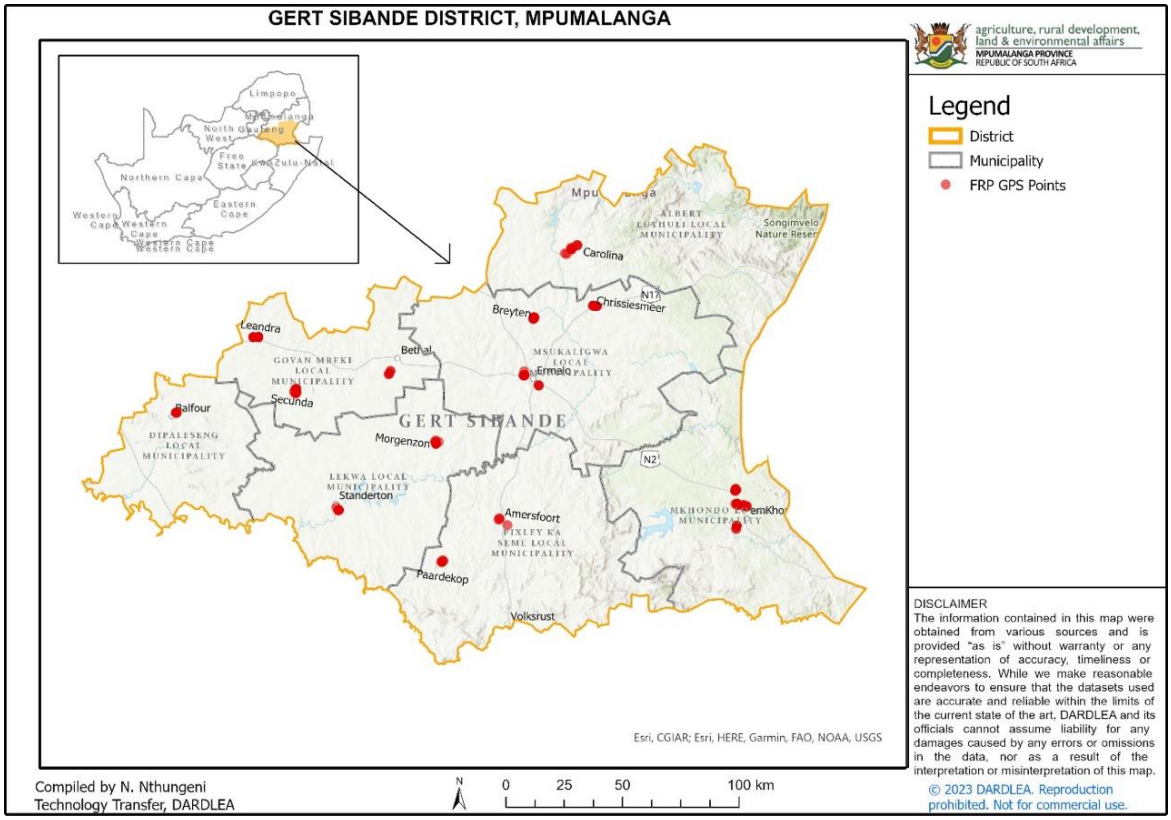


Figure 3.1: Gert Sibande District Local Municipality with GPS points for data collected
Source: DARDLEA GIS unit

3.2.2. Data collection

The study participants were identified using the snowball sampling method since no sampling frame exists for free-roaming pig farmers (FRP). The first FRP farmer in each community was identified through the assistance of the district or municipal animal health professional, and thereafter, snowball sampling was utilised to recruit other farmers into the study. For the pigs, the stratified random sampling method was used to select pigs used for ecto- and endo-parasite samples. The pig population that made up the study population was divided into five strata (groups) and included: 33 boars (12 months + male), 78 sows (12 months + female), 33 finishers (8–11 months), 64 growers (5–7 months) and 75 piglets/weaners (1–4 months). In each stratum, one pig was randomly selected. A total of 283 samples were collected from 283 pigs from seven different municipalities in GSDM. In addition, data were collected from 124 farmers using structured questionnaires.

An outbreak of ASF in most study regions followed by an outbreak of Foot and Mouth disease in cattle in a nearby province delayed the onset of the study. Dipaliseng, Lekwa, Govan Mbeki, and Msukaligwa were among the municipalities devastated by

the earlier outbreaks of ASF, which occurred between 2020 to early 2022. To minimise the risk of spreading infectious diseases (ASF), this investigation was therefore postponed, re-planned and a heightened biosecurity protocol integrated into the survey plan. Permission to begin data collection was acquired from the state veterinarian. All biosecurity protocols were strictly followed at all times, including separating farm areas into low and high-risk areas, visiting the low-risk farms first, changing shoe covers where necessary, reducing interaction directly with the pigs, not visiting more than three farms per day, using disinfectant to sanitise hands, shoes and other equipment used such as pig holder and pig handling boards. No single case of ASF or any other infectious disease in pigs was recorded in all the areas where the research was carried out, both during and after data collection.

3.2.3. Pig handling

To reduce the risk of trauma and injury to the pigs and the handler, standard pig handling practices were followed. Pigs were managed in line with the Animal Protection Act 71 of 1962 by following standard procedures for handling violent animals in the pig industry. To restrain the pigs during data collection, plastic handling boards and pig snares were used. To minimise stressing the pigs, data were collected as quickly as feasible taking cognisance of the five welfare principles of Webster (Webster, 2016).

Small pigs were captured by their hind legs and pulled up by placing a hand beneath the piglet's chest to support its weight. To restrict movement during handling, the piglets were carefully restrained. By doing so, the researcher and other team members were able to collect the samples without compromising the welfare of the piglets. After the procedures of collecting samples were completed, the piglet was placed on the floor as soon as possible, by letting both front limbs contact the floor surface before being gently lowered onto their hind legs. To minimise the risk of spreading infections between pigs, the equipment used was disinfected between procedures in water containing F10 (an antiseptic solution containing benzalkonium chloride and polyhexanide).

Pigs weighing more than 10 kg were caught using a pig snare. As shown in Appendix 3.1d, the snare restraint was manoeuvred into the mouth and placed behind the canine

teeth (tusks), and held gently, safely, yet firmly without compromising the welfare of the pig. The pig was freed from the pig snare as quickly as possible by gently releasing the snare.

3.2.4. Faecal sample collection

Fresh faeces were collected directly from the pig rectum through gentle rectal massage. However, if the pig voided faeces in the presence of the researcher, the core of the freshly voided faeces was collected. Approximately 5 g of faeces were collected from the rectum of each pig. A new sterile latex glove was used for each pig, or from the freshly voided faeces. The gloves were lubricated with liquid paraffin before insertion of the gloved fingers into the rectum. The samples were stored in a sterile cooler bag with ice packs to maintain the integrity of the sample. The collected samples were delivered to Mpumalanga Provincial Veterinary Laboratory (MPVL) on the same day of collection and stored in the refrigerator (2–8 °C). The examination of the samples was done within three days of collection.

3.2.5. Collection of skin scrapings

Skin scrapings were done in different areas of the pigs (i.e. on the neck, in the inner part of the ear, the tip of the tail or back of the ear). Care was taken to minimise bleeding from the skin by rubbing a few drops of liquid paraffin into the skin before the surface was extensively scraped with the scalpel. Masking tape was used after the samples had been assembled to seal the slides. The slides were examined under a stereo microscope.

The collected lice were placed in 5% formalin or methylated spirits in the plastic specimen following the procedure used by Laha (2015). Procedures described by previous researchers were used to identify the lice (Lapage, 1968; Odo *et al*., 2016). Standard laboratory protocols and the standard operating procedures (SOPs) of MPVL were used to process all samples. All the sampled pigs were sprayed with wound spray (Zoetis Terramycin wound spray [oxytetracycline hydrochloride 4 g and blue marker dye]), to avoid flies and infection after taking skin scrapings.

A form, which contained the following information, accompanied the pig samples: unique code, municipality, age, sex, weight, breed, and body condition. The form was completed for each pig that was sampled (see Appendix 2).

3.2.6. Faecal egg count

The McMaster approach as simplified by Roepstroff and Nansen (1998) and Kaufmann (1996), was used to conduct faecal egg counts (FECs). The FECs were expressed as eggs per gram (EPG) of faeces. An empty bottle was placed on a weighing scale tared to 0 g for each sample, and 2 g of faeces was inserted into the empty bottle. The 2 g of faeces were thoroughly mixed with 58 ml of 40% sugar solution (400 g sugar mixed with 1 000 ml hot water and 20 ml of 10% formalin to prevent growth of fungus) using a mortar and pestle. A plastic pipette was used to pick the mixture and fill the McMaster counting chamber. The McMaster slide was loaded and then left to stand for five minutes to allow the eggs to float to the surface of the 40% sugar solution. Using the microscope (10x magnification), the eggs were counted in the grid of the two chambers on the McMaster slide. The sheep counter was used to count the eggs. Then, all of the available eggs were identified, and the number of eggs was recorded.

3.2.7. Statistical analysis

Matched variables and the laboratory data from the parasitological analysis were entered in a Microsoft Excel spreadsheet version 2016 (Microsoft Corporation, Redmond, Washington, USA). Pairwise correlation (*r*) analysis was conducted to determine correlated association of pig characteristics (sex, age, body conditions score and breed) with the parasites from the faecal and skin scraping samples. Significant *p* values was set at ≤ 0.05 using Bonferroni-adjusted significance level in Stata 15.0 (StataCorp LLC, College Station, Texas, United States). Furthermore, the prevalence of parasites was assessed in different age groups of pigs using multi response crosstabs of SPSS V28.0 (IBM corp 2021). The chi-square test (X^2) was used to assess the distribution of parasites in different age groups of FRP in GSDM peri-urban areas. The multivariate analysis of variance (MANOVA) was used to estimate the marginal mean of parasites according to municipality. The cross tabulation was used to assess the relationship between parasites and the age of the pig, parasites and the municipality, parasites and the type of breed, and finally parasites and the body condition score of the pig, as indicated by Coffey *et al*. (1999).

3.3. Results

3.3.1. Animal characteristics correlated with parasites

A total of 283 pigs of various ages were sampled. The association between *Ascaris suum* and body condition was weak but significant (r = 0.24; $p < 0.05$). Similarly, the association between *Ascaris suum* and *H. suis* was weak but significant (r = 0.20; $p < 0.05$), while the correlation between *Ascaris suum* and *Coccidia* spp. was moderate (r = 0.49; $p < 0.05$). In addition, *Trichuris suis* was a moderate positive predictor for *Coccidia spp*. (r = 0.37; $p < 0.05$) but a weak positive predictor for *Strongylids* (r = 0.24; $p < 0.05$). Finally, the association between the *Strongylids* and *T. suis* was moderate (r = 0.48; $p < 0.05$) (Table 3.1).

Table 3.1: Pairwise correlation analysis of animal characteristics and observed parasites from pigs, Mpumalanga Province

	Sex	Age	Breed	Body condition	*H. suis*	*S. scabiei*	*A. suum*	*Coccidia spp.*	*Fasciola hepatica*	*T. suis*	*Strongylids*
Sex	1.000										
Age	**-0.197***	1.000									
Breed	0.002	0.022	1.000								
Body condition	-0.038	-0.190	0.112	1.000							
H. suis	0.030	-0.175	0.123	0.074	1.000						
S. scabiei	-0.074	0.049	-0.116	0.070	0.089	1.000					
A. suum	-0.042	-0.090	0.039	**0.240***	**0.200***	-0.080	1.000				
Coccidia spp	-0.048	0.054	0.008	0.005	-0.127	-0.024	**0.490***	1.000			
Fasciola hepatica	0.022	0.034	0.143	0.073	0.178	-0.094	0.154	0.111	1.000		
Trichuris suis	-0.033	0.068	0.070	0.169	-0.063	-0.041	0.120	**0.366***	0.041	1.000	
Strongylids	-0.021	0.059	-0.026	0.096	-0.0004	-0.006	0.145	**0.244***	0.058	**0.482***	1.000

***Note**: H. suis = Haematopinus suis; S. scabiei = Sarcoptes scabiei; T. suis = Trichuris suis; A. suum = Ascaris suum, Sex (Female = 0; Male = 1); Age (≤ 1 year = 0; ≥ 1 year = 1); Breed (exotic = 0; indigenous and indigenous crosses = 1); Body condition (ideal, fat or obese = 0; thin or emaciated = 1); H. suis (Negative = 0; Positive = 1); Sarcoptes scabiei (Negative = 0; Positive = 1); Ascaris suum (Negative = 0; Positive = 1); Coccidia spp. (Negative = 0; Positive = 1); Fasciola hepatica (Negative = 0; Positive = 1); Trichuris suis (Negative = 0; Positive = 1); Strongylid nematodes (Negative = 0; Positive = 1).*represents significance level of p < 0.05. All bold values were significant.*

***Interpretation of pairwise correlation analysis:** The higher the absolute value of the correlation coefficient, the stronger is this relationship. Typically, absolute values between 0 and 0.29 are considered weak correlations, 0.3–0.49 are considered moderate, while anything between 0.5 and 1 is treated as a strong correlation.*

3.3.2. Distribution of parasites in different free-roaming pig age groups

Sarcoptes scabiei was commonly isolated in all age categories, with the highest prevalence observed in pigs aged ≥ 12 months (41.6%) and ≤ four months (28.0%) (Tables 3.2 and 3.3). *Coccidia spp.* showed a similar pattern, with a high prevalence observed in pigs aged ≥ 12 months (40.8%) and ≤ 4 months (29.6%). The prevalence of *Haematopinus suis* did not change significantly across three age groups: > 12 months and older (30.7%), four months (29.5%), and five to seven months (25.0%). *Trichuris suis, Strongylids, Fasciola hepatica*, and *Moniezia expansa* were all quite predominant in pigs 12 months or older, with 50.0%, 51.7%, 50.0%, and 50.0%, respectively (Table 3.2).

Table 3.2: Distribution of parasites in different FRP age groups in GSDM, MP.

	Age of the pigs			
Parasites	≤ 4 Months (%)	5–7 Months (%)	8–11 Months (%)	≥ 12 Months (%)
Haematopinus suis	29.5	25.0	14.8	30.7
Sarcoptes scabiei	28.0	19.7	10.7	41.6
Ascaris suum	26.2	28.0	12.1	33.6
Coccidia spp	29.6	24.3	5.3	40.8
Trichuris suis	15.8	26.3	7.9	50.0
Strongylids	10.3	34.5	3.4	51.7
Fasciola hepatica	0.0	50.0	0.0	50.0
Moniezia expansa	0.0	16.7	33.3	50.0
Siphonaptera	28.6	57.1	0.0	14.3

Note: Total number of pigs sampled was n=283.

3.3.3. Observational findings in peri-urban areas of Gert Sibande District Municipality

Pigs were seen free-roaming in sewerage areas, streams, immobile dams and crossing roads. In terms of feeding, the following were observed: pigs were fed dead chicken and swill, feeders used without cleaning or disinfecting and were being fed from the soiled floor. Unwashed drums were used as storage for swill. Bones, plastics and kitchen utensils were also observed in the pig pens.

Table 3.3: Multi-response frequency of parasite recorded from laboratory test results in GSDM.

Parasites	Responses (*n*)	Proportion of total parasites observed (%)	True prevalence of cases observed (%)
Haematopinus suis	88	14.4	31.1
Sarcoptes scabiei	178	29.2	62.9
Ascaris suum	107	17.6	37.8
Coccidia spp.	152	25.0	53.7
Trichurus suis	38	6.2	13.4
Strongylid nematodes	29	4.8	10.2
Fasciola hepatica	4	0.7	1.4
Moniezia expansa	6	1.0	2.1
Siphonaptera	7	1.1	2.5
Total	609	100.0	NA

Note: The EPG ranged from 100 to 5 200; NA = Not applicable.

3.3.4. Prevalence of parasites in the peri-urban free-roaming pigs of Gert Sibande District Municipality, Mpumalanga Province

Sarcoptes scabiei and *Coccidia* spp. were the most frequently recovered parasites in peri-urban FRP of GSDM accounting for 29.2% and 25.0% of the total parasites recovered and observed in 62.9% and 53.7% of the pigs, respectively (Table 3.3). The following parasites were also observed in the study area: *A. suum* (37.8%), *H. suis* (31.1%), *Trichuris suis* (13.4%), and *Strongylid nematodes* (10.2%) (Table 3.3). Other parasites (*Siphonaptera* spp., *Moniezia expansa* and *Fasciola hepatica*) were less frequently recovered from the FRP in the GSDM.

The prevalence of parasites in FRP from the different municipalities varied. Mkhondo had the highest prevalence of *H. suis* (50.0%), followed by Msukaligwa (37.5%) and Govan Mbeki (12.5%). On the other hand, *H. suis* was not isolated in certain municipalities such as Chief Albert Luthuli Municipality (CALM), Lekwa, Pixley ka Seme, and Dipaliseng (Table 3.4). *Sarcoptes scabiei* was found in 9.6% of the pigs tested in each of CALM and Dipaliseng. Govan Mbeki (28.7%) and Mkhondo (15.2%), each yielded a higher number of positive samples. Only 7.2% of the pigs from each of

Pixley ka Seme and Lekwa were positive. The municipalities with a high percentage of pigs positive for *Ascaris suum* were Mkhondo (41.1%), followed by Govan Mbeki (30.8%). Dipaliseng (11.2%), Msukaligwa (9.3%), and CALM (7.5%) had lower *A. suum* prevalence. All pigs tested negative for *A. suum* in the municipalities of Pixley ka Seme and Lekwa (Table 3.4).

In GSDM peri-urban areas, Govan Mbeki (39.5%) reported the highest prevalence of FRP that were positive for *Coccidia* spp. This was followed by Mkhondo (22.4%) and Dipaliseng (9.7%), with the other municipalities showing lower numbers of positive FRPs (Table 3.4). None of the pigs (0%) in Pixley ka Seme tested positive for *Coccidia* spp. *Trichuris suis* was discovered in only three municipalities, with Dipaliseng having the highest percentage of positive cases (71.0%). Mkhondo (23.7%) and CALM (5.3%), on the other hand, had lower parasite burdens than Dipaliseng (Table 3.4). *Trichuris suis* was not found in the other four municipalities. *Strongylid* was the least observed parasite in the GSDM, with Dipaliseng having (37.9%) the highest prevalence rate, followed by Mkhondo (31.1%), Govan Mbeki (20.7%), and Msukaligwa (10.3%). In the remaining three municipalities, *Strongylid* detection was negative.

Surprisingly, *Fasciola hepatica* and *Siphonaptera* fleas were only reported in Mkhondo and Msukaligwa respectively (Table 3.4). *Moniezia expansa* was found in two municipalities, CALM and Govan Mbeki, with each reporting a 50% prevalence (Table 3.4).

Table 3.4: Distribution of pig parasites according to municipality in GSDM

Parasites	Msukaligwa (%)	Mkhondo (%)	Govan Mbeki (%)	CALM (%)	Dipaliseng (%)	Pixley ka Seme (%)	Lekwa (%)
H. suis	37.5	50.0	12.5	0.0	0.0	0.0	0.0
Sarcoptes scabiei	22.5	15.2	28.7	9.6	9.6	7.2	7.2
Ascaris suum	9.3	41.1	30.8	7.5	11.2	0.0	0.0
Coccidia spp.	5.9	22.4	39.5	3.9	19.7	0.0	8.6
Trichuris suis	0.0	23.7	0.0	5.3	71.0	0.0	0.0
Strongylids	10.3	31.1	20.7	0.0	37.9	0.0	0.0
Fasciola hepatica	0.0	100	0.0	0.0	0.0	0.0	0.0
Moniezia expansa	0.0	0.0	50.0	50.0	0.0	0.0	0.0
Siphonaptera spp.	100	0.0	0.0	0.0	0.0	0.0	0.0

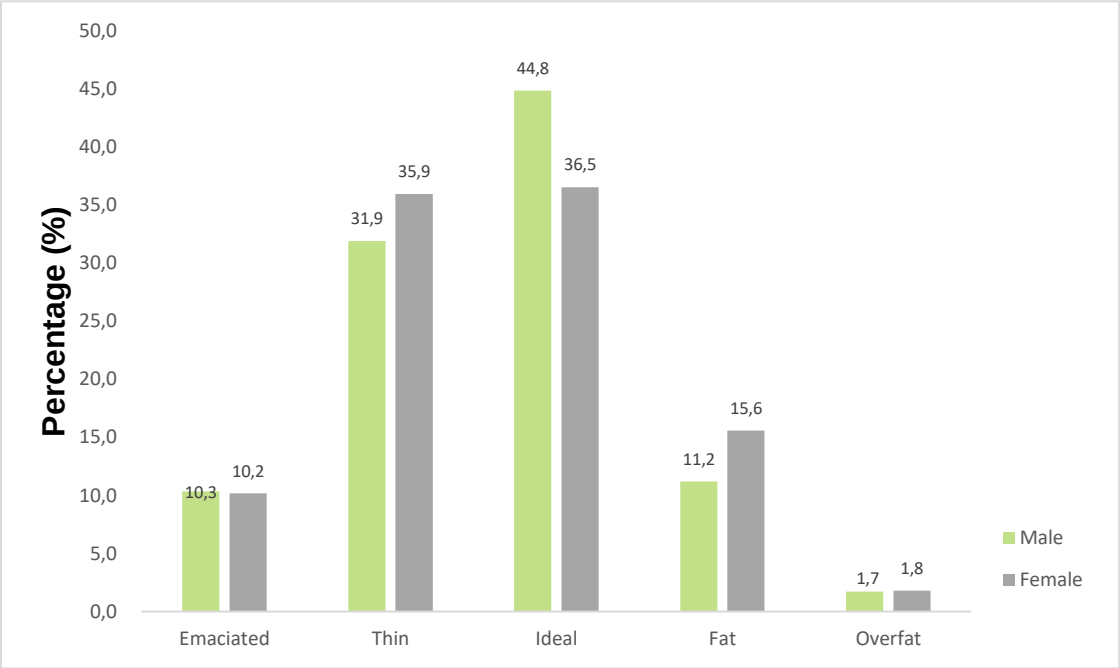
Note: Only the parasites that tested positive are listed in Table 3.5 by percentages. CALM = Chief Albert Luthuli Municipality.

Table 3.5: Prevalence of parasites in various pig breed types and sex

	Type of breed			**Sex**	
Parasites	Exotic breed (%) (*n* = 215)	Cross of exotic breed & Indigenous breed (%) (*n* = 37)	Indigenous breed (%) (*n* = 31)	Male (%) (*n* = 116)	Female (%) (*n* = 167)
Haematopinus suis	68.2	19.3	12.5	43.2	56.8
Sarcoptes scabiei	79.8	14.0	6.2	38.2	61.8
Ascaris suum	73.8	15.0	11.2	38.3	61.7
Coccidia spp.	75.7	15.1	9.2	38.8	61.2
Trichuris suis	68.4	23.7	7.9	36.8	63.2
Strongylids	79.3	20.7	0.0	37.9	62.1
Fasciola hepatica	25.0	50.0	25.0	50.0	50.0
Moniezia expansa	100	0.0	0.0	33.3	66.7
Siphonaptera spp.	100	0.0	0.0	42.9	57.1

Less than half of the male (44.8%) and fewer females (36.5%) had an ideal BCS (Figure 3.2). Approximately 42.2% and 46.1% of the male and female FRP in GSDM had a BCS that ranged from emaciated to thin and only 12.9% and 17.4% male and female had fat to overfat BCS respectively.

Figure 3.2: The body condition score of pigs by sex.



Note: The body condition score (BCS) was graded according to standards (Canadian Pork Council: https://www.cpc-ccp.com/uploads/userfiles/files/ACA-Appendix-10.pdf.

The exotic breeds raised in the peri-urban free-roaming settings were more vulnerable to different parasites. As shown in Table 3.5, a high number of exotic pigs were positive for *H. suis* (68.2%), *Sarcoptes scabiei* (79.8%), *Ascaris suum* (73.8%), *Coccidia* spp. (75.7%), *Trichuris suis* (68.4%), *Strongylids* (79.3%), *Moniezia expansa* (100%) and *Siphonaptera* spp. (100%). The exception was *Fasciola hepatica*, for which a higher proportion (50%) of parasite-positive pigs was observed among the crosses as compared to both the exotic breed and indigenous breeds. The indigenous breeds had the least parasite burden.

In terms of sex, female pigs 167 (59.10%) had a higher parasite load than the male pigs 116 (40.98%) (Table 3.5). The exception was *Fasciola hepatica* which was found in equal proportions (50%) in both male and female pigs (Table 3.5).

The pigs that had a thin or ideal BCS tended to carry a higher parasite burden compared to the other BCS categories. The least parasite burden was found among the fat and overfat pigs. The highest proportion of pigs that tested positive for *Moniezia expansa* were pigs with an ideal (33.3%) and fat (33.3%) BCS. On the other hand, thin pigs (75.0%), showed a higher proportion of *Fasciola hepatica* infestation. Pigs with ideal body conditions included the highest proportion of pigs (71.4%) that were positive for *Siphonaptera* infestation (**Table 3.6**).

Table 3.6: Frequency of parasites based on the different pig body condition score

Parasites	Emaciated (%)	Thin (%)	Ideal (%)	Fat (%)	Overfat (%)
Haematopinus suis	9.1	40.9	37.5	12.5	0.0
Sarcoptes scabiei	10.7	36.5	39.3	12.4	1.1
Ascaris suum	16.8	43.0	28.0	10.3	1.9
Coccidia spp.	11.2	33.6	40.8	12.5	2.0
Trichuris suis	15.8	50.0	34.2	0.0	0.0
Strongylids	20.7	37.9	37.9	3.4	0.0
Fasciola hepatica	0.0	75.0	25.0	0.0	0.0
Moniezia expansa	16.7	16.7	33.3	33.3	0.0
Siphonaptera spp.	0.0	28.6	71.4	0.0	0.0

3.4. Discussion

Free-roam pig keeping appears to contribute to the prevalence of the various endo- and ectoparasites observed in this study. Although results of the prevalence of parasites reported here are not as high as found in free-roaming pigs elsewhere, they are consistent with results from a study that was done in Botswana in which the following was observed: *Ascaris suum* – 54.55%; *Trichostrongylus* spp. – 20.45% and *Trichuris suis* – 6.82% (Nsoso *et al*., 2000). Results of the present study are also consistent with those reported from Romania (Băieş *et al*., 2022) in which a high prevalence of ectoparasites was observed.

In this study, pigs were discovered scavenging in sewage, streams, dumping areas, being fed dead chickens, feeding from soiled flooring, and being fed swill. The overall prevalence of ecto- and endoparasites was 91.2%. Similarly, a study from Nepal reported a high prevalence of 91% (Adhikari *et al*., 2021). These results are also consistent with results of a study from Burkina Faso in which a prevalence of 92.7%

was observed (Tamboura *et al*., 2006). However, findings of the present study contrasted with those from a study conducted in the Free State Province (SA) that observed a lower prevalence (79.2%) (Nwafor et al., 2019).

Sarcoptes scabiei as well as *Coccidia* spp., *Ascaris suum* and *Haematopinus suis* were the most commonly detected parasites among FRP in the peri-urban areas of Mpumalanga Province. On the other hand, *Siphonaptera* spp., *Moniezia expansa* and *Fasciola hepatica* were the least prevalent parasites in the study area. These finding were not surprising as most of these parasites are soil-borne and the FRP may encounter them frequently while searching for food in the environment (Omudu and Amuta, 2007).

The recovery of *Moniezia expansa*, a large tapeworm commonly associated with the small intestines of ruminant livestock (i.e. sheep, goats and cattle) is a significant finding. This parasite has been reported as an incidental finding in pigs from a few studies globally. For example, Gomez-Puerta *et al*. (2008) in Peru, Matos *et al.* (2011) in Mozambique and Adelakun *et al*. (2021) in Nigeria have also reported the parasite in their studies. The present study focused on FRP, and because some farmers in the study area employed mixed farming methods, the FRP may interact freely with other livestock species; this could explain the finding of *Moniezia expansa* in our study. This view is supported by Matos *et al.* (2011) who linked the occurrence of *Moniezia expansa* in pigs to a scenario in which pigs picked up the parasite while grazing on the same pasture with cattle and goats. It is plausible that this *Moniezia expansa* can gain entry into pigs through food and water sources (Soulsby, 1982). This is supported by the fact that the prevalence of *Moniezia expansa* was significantly higher in CALM (0.5%, $p < 0.05$) and Govan Mbeki (0.5%, $p > 0.05$), areas where pigs and goats shared facilities for night kraaling. This observation will need further evaluation.

Fasciola hepatica was observed in 1.4% of the pigs. However, this was lower than previously reported in Ethiopia (2.8%) by Tomass *et al.* (2013). The researchers in the Ethiopian study linked the occurrence of *F. hepatica* in pigs to irrigated urban and peri-urban crop production practices, in which crops were watered with wastewater that may contain the intermediate hosts of *F. hepatica*. In this study, pigs were observed consuming water from dumping sites, burst sewerage streams, and still rain dams.

Therefore, some of the pigs might have inadvertently eaten the snail hosts. However, a similar study in Uganda failed to detect *F. hepatica* in pigs (Roesel *et al*., 2017).

The proportion of pigs carrying ectoparasites (96.5%) in this study was higher than those reported in Mbeya in Tanzania (84%) (Braae *et al.,* 2013) and in Nigeria (50.75%) (Odo *et al*., 2016). *H. suis* was predominantly identified around the ears, neck, and abdomen (Braae *et al*., 2013), and these may have been contracted through direct contact with neighbouring pigs and/or during pasturing (Damriyasa *et al*., 2004; Braae *et al*., 2013). According to Islam *et al.* (2006), *H. suis* causes hair loss, skin lesion, and thickening of the skin in pigs. Although previous researchers have suggested a link between *H. suis* and ASF or swine pox (Sanchez and Badiola, 1966; Doster, 1995; Permin *et al*., 1999; Damriyasa *et al*., 2004), our results did not confirm this suggestion. Based on the veterinary health records in the province, the Mkhondo municipality has never had an ASF outbreak, yet the prevalence of *H. suis* was 50.0%. However, the other two municipalities that had *H. suis* (Msukaligwa at 37.5% and Govan Mbeki at 12.5%) both had ASF outbreaks in the previous years. Furthermore, Dipaliseng and Lekwa have reported numerous outbreaks of ASF and, yet, all pigs from these municipalities tested negative for *H. suis*. It is worth noting that this is the first report of *H. suis* in pigs from Mpumalanga Province.

Around the world, *Sarcoptic* mange is the most frequent external parasite of pigs. This is consistent with findings reported here, with *Sarcoptes scabiei* recovered from 62.9% of the FRPs included in the study. It is not unusual to report more than 50% prevalence for *Sarcoptic* mange in pigs (Odo *et al*., 2016). For example, Islam *et al*. (2006) reported a prevalence of 57.30% in Bangladesh, while Kagira *et al*. (2013) reported 63.7% in Kenya. A high proportion of infected sows infested with ectoparasites has been related to a high rate of piglet mortality (Ózsvári, 2018). However, Jufare and colleagues have linked variation in the proportion of pigs infested with parasite to changes in management systems, pig breed, nutrition, climatic conditions, animal health practices, and government policies, which are the key barriers in pig farming. In this study, the high occurrence of parasites is attributed to the fact that pigs were allowed to roam freely in the peri-urban area.

Although the overall burden of *A. suum* infection in the peri-urban FRP of GSDM in Mpumalanga Province was 37.8%, research in the neighbouring province of Free State (SA) found a higher prevalence of *Ascaris suum* (44.5%). Moreover, a higher percentage of pigs aged 12 months and older tested positive for *A. suum* (33.6%).

Previous results have also noted *A. suum* as the most common parasite among scavenging pigs (Kumar *et al*., 2002; Ngowi *et al*., 2004; Tamboura *et al*., 2006; Matos *et al*., 2011; Kagira *et al*., 2013; Odo *et al*., 2016). The high infestation with *A. suum* among growing pigs has been documented as a cause of poor growth, anaemia and even death (Nsoso *et al*., 2000; Ngowi *et al*., 2004; Tamboura *et al*., 2006; Tomass *et al*., 2013; Taylor, 2015; Jufare *et al*., 2015). The *A. suum* eggs can survive inclement weather and some chemicals, and they may last for extended periods of time while still being viable and infectious (Roepstorff and Nansen, 1998). This could explain the high prevalence of *A. suum* in FRPs in the present and previous studies.

The statistically significant relationship observed between the occurrence of *A. suum* and *Coccidia spp*. suggests that a high prevalence of *A. suum* in young pigs seven months and younger could be linked to a high prevalence of *Coccidia* spp. in these age groups. Furthermore, this can be understood to mean that pigs infected with *A. suum* are more likely to be infected with *Coccidia* spp. or vice versa.

Results of the present study did not demonstrate the existence of an association between age and different parasites ($p < 0.05$). This contrasts with findings of studies conducted in Northern Ethiopia and Bangladesh, which found an association between parasites and age (Islam *et al*., 2006). On the other hand, this study agreed with findings of the study by Tomass *et al*. (2013), who found no association between sex and parasites.

Strongylid nematodes were observed in only 10.2% of the pigs tested in the present study. However, this was slightly higher than the 6.6% reported in South Korea by Lee *et al.* (2022). The Mkhondo municipality, with a percentage of 31.1%, had the highest prevalence of *Strongylids*. Furthermore, *Strongylids* were most prevalent in emaciated to thin pigs (58.6%) and pigs older than 12 months (51.7%). The high percentage of Strongylids may be attributed to Mkhondo municipality's high rainfall, which ranges

from 701 mm to 1 200 mm when compared to other municipalities. As previously stated, the majority of *Strongylids* were detected in older pigs, and this could be attributable to the fact that older pigs are usually large and hence are not usually included in the pigs that are treated. This is because it is difficult to handle large pigs without proper handling equipment.

Coccidia, a protozoan parasite was observed in 53.7% of the peri-urban FRP in GSDM. This is much higher than the 0.3% recorded in South Korea (Lee *et al*., 2022); 5.6% in Ethiopia (Abdu & Gashaw, 2010); 29.9% in China (Gong *et al*., 2021) and 12% in Kenya (Jufare *et al*., 2015). However, findings of the present study are lower than the 72.7% observed in Free State (Nwafor *et al*., 2019). The highest proportion of pigs positive for *Coccidia* was seen in Govan Mbeki municipality (39.5%; $p < 0.05$), Msukaligwa (22.4%; $p < 0.05$), and Dipaliseng (19.7%; $p < 0.05$). *Coccidia spp.* was more prevalent in female pigs (61.2%) and pigs with a thin to ideal body condition score (74.4%). Exotic breeds (75.67%) and 12-month-old pigs (40.8%) were the most afflicted by *Coccidia spp*. Meanwhile, in China, the prevalence of *Coccidia* infection was 19.9% in the suckling and 26.2% in the finishing age groups.

Coccidia infections had a moderately positive correlation with the presence of other parasites including *T. suis* ($r = 0.366$; $p< 0.05$) and *Strongylids* ($r = 0.244$; $p < 0.05$). The prevalence of *Coccidia* in this study was associated with the observed feeding of dead chicken (poultry), continuous use of feeders without cleaning, and drums used for swill storage that were not cleaned or sterilised. The high prevalence of *Coccidia* in pigs causes diarrhoea, anorexia, weight loss in piglets, haemorrhage, reduced weight gain (Dione *et al*., 2018; Nwafor *et al*., 2019; Gong *et al.,* 2021). In addition, *Strongylids* have previously been linked to diarrhoea in pigs, which can lead to weight loss and even death. This could explain why pigs in this study that had *Strongylids* were found to have BCS that varied from emaciated to thin. The negative effects of the parasites causes stunted growth in the pig, hence delaying marketing which can exacerbate financial loss in the pig industry.

Trichuris suis, had a lower prevalence in the GSDM (13.4%) but a higher prevalence in Dipaliseng (71.0%; $p < 0.05$). Female pigs and pigs older than 12 months were the

most infested with *T. suis*, (63.2% and 50%, respectively). Furthermore, *T. suis* was most prevalent in exotic breeds (68.4%) and in pigs with BCS ranging from emaciated to thin (65.8%). However, no pigs with BSC ranging from fat to overfat were infected with *T. suis*. These findings suggest that *T. suis* is associated with loss of weight and poor BCS among pigs, which can result in low profit and poor pig performance.

The high percentage of *T. suis* observed in this study can be linked to poor management or husbandry techniques associated with FRP in the study area. It could also be explained by the fact that *T. suis* eggs are resilient and can tolerate unfavourable environmental circumstances for up to four years (Urquhart *et al.*, 2003; Nwafor *et al*., 2019). This increases the risk of exposure of FRPs to the eggs of *T. suis*.

Siphonaptera flea is not a common parasite and hence it has rarely been studied in pigs. Of note is that *Siphonaptera* flea was discovered in several peri-urban areas of Msukaligwa. The flea was most common in female pigs (57.1%), exotic breeds (100%), pigs with thin to ideal BCS (85.7%), and younger than seven months (100%). Considering that *Siphonaptera* feeds on the skin and that it occurs in exotic breeds and young pigs with ideal BCS, it was most likely discovered in young pigs, with soft skins like that of exotic breeds, rather than indigenous breeds.

Finally, previous workers have confirmed co-infestations with various parasites among free-roaming and intensively managed pigs, with a significant impact on their productivity (Kagira, 2010; Greve, 2012; Băieş *et al*., 2022). Co-infections may lead to severe negative effects (clinical signs, duration, and treatment) associated with the impact of multi-parasitism on pig health either through synergistic or antagonistic interaction, which may be complicated by resident microbial pathogens (Vaumourin *et al*., 2015; Kouam *et al*., 2022). Parasites, on the other hand, play a significant role as a hidden cause of economic loss, including slower growth rate, weight loss, and fewer litters of small size (Pattison *et al*., 1980; Wilson & Swai, 2014; Odo *et al*., 2016). There is an urgent need to educate farmers who allow pigs to roam freely in peri-urban areas concerning the threat of parasites and preventative measures that pig farmers can adopt.

According to Sowemimo *et al.* (2012), parasite infestation can be prevented or minimised by adopting appropriate management strategies such as routine daily cleaning and disinfection of the environment, feeding of high-quality commercial feed, and timely application of efficient anthelminthic drugs. Furthermore, according to Nonga and Lugendo (2015), understanding the disease's spectrum and epidemiology is critical in developing effective control strategies targeted at enhancing the country's pig industry. At the end of this investigation, an itinerary with the occurrence of parasites in each municipality and the necessary control measures will be established for FRP farmers.

Free-roaming pigs carry a variety of ecto- and endoparasites in the peri-urban areas of GSDM, Mpumalanga Province with implications on animal and human health. This may directly negatively affect the performance and productivity of pigs reared under FRPs farming system. *Ascaris suum* and *T. suum* were observed in this study. These parasites have zoonotic potential and hence the observed prevalence of these parasites in this study is of serious public health concern (Poudel, 2018). According to Taylor (2015), zoonotic infections are a major threat for public health and other animals. Furthermore, de Silva *et al*. (2003) linked the *T. suis* and *A. suum* to the severity of *A. lumbricoides* and *T. trichiura*, known to infect 1 221 and 795 million individuals worldwide, respectively. This adds to the significance of observing *A. suum* and *T. suum* in the free-roaming pigs in the study area.

3.5. Conclusion

A total of nine different parasites were found including *H. suis, S. scabiei, A. suum, F. hepatica, T. suis, Strongylids, Coccidia* spp*., M. expansa,* and *Siphonaptera* spp. Parasitic infestation and infection is very high among FRPs, with approximately nine (n=9) out of every 10 FRP in Gert Sibande District Municipality positive for at least one or more parasites. These findings have implications for performance in these pigs characterised by lower growth rates, lower sow and boar reproductive efficiency, and lower feed conversion efficiencies with resultant decreased income return in the pig farming industry.

Findings of this study confirmed that sex, age, breed, and body condition scores are not good predictors of internal and external parasitosis in pigs. In addition, pigs older

than 12 months were more susceptible to parasites than younger pigs. It was also found that the most troublesome parasites in the peri-urban free-roaming pigs of GSDM, Mpumalanga Province, were *S. scabiei* and *Coccidia* spp. Female pigs, pigs with thin or ideal body condition scores, and exotic breeds were most likely to have parasite infestations under the peri-urban free-roaming practice. With the advent of numerous diseases in the Republic of South Africa, agricultural regulations (peri-urban farming) should be revised in order to control and prevent parasites in FRPs in peri-urban areas. Policy makers, animal researchers and veterinary services must focus on developing policies and risk communication and community engagement (RCCE) materials, which target pig farmers in peri-urban areas such as Gert Sibande District Municipality, Mpumalanga Province to reduce disease burdens in both humans and animals.

3.6. References

Abdu, S., Gashaw, A., 2010, Production system dynamism and parasitic interaction of swine in and around Holetta, Ethiopia, *Ethiopian Veterinary Journal* 14(1), pp.71–82.

Adebisi, O.R., 2008, Gastro-intestinal helminths and public health: Overview of a neglected sector, *The Internet Journal of Veterinary Medicine* 4(2), pp.72–78.

Adelakun, O.D., Abiola, J.O., Akande, F.A., 2021, Moniezia expansa in intensively raised pigs: A Possible First Report in Nigeria, *Nigerian Veterinary Journal* 42(2), pp.123–128.

Adhikari, R.B., Adhikari Dhakal, M., Thapa, S., Ghimire, T.R., 2021, Gastrointestinal parasites of indigenous pigs (*Sus domesticus*) in south-central Nepal, *Veterinary Medicine and Science* 7(5), pp.1820–1830.

Băieş, M.H., Boros, Z., Gherman, C.M., et al., 2022, Prevalence of swine gastrointestinal parasites in two free-range farms from nord-west region of Romania, *Pathogens* 11(9), p.954 .https://doi.org/10.3390/pathogens11090954.

Braae, U.C., Ngowi, H.A., Johansen, M.V., 2013, Smallholder pig production: incidence and risk factors of ectoparasites, *Veterinary Parasitology* 196(1–2), pp.241–244.

Coffey, R.D., Parker, G.P., Laurent, K.M., 1999, Assessing sow body condition. Ky. Coop. Ext. Serv. Rep. No. ASC-158.

http://www2.ca.uky.edu/agcomm/pubs/asc/asc158/asc158.pdf. (Accessed 13 October 2023).

Damriyasa, I.M., Failing, K., Volmer, R., Zahner, H., Bauer, C., 2004, Incidence, risk factors and economic importance of infestations with *Sarcoptes scabiei* and *Haematopinus suis* in sows of pig breeding farms in Hesse, Germany, *Medical and Veterinary Entomology* 18(4), pp.361–367.

De Silva, N.R., Brooker, S., Hotez, P.J., Montresor, et al., 2003, Soil-transmitted helminth infections: Updating the global picture, *Trends in Parasitology* 19(12), pp.547–551.

Department of Cooperative Governance and Traditional Affairs (DCGTA), 2020, A profile and Analysis of Gert Sibande District. Available at: Final-Edited-Gert-Sibande-DM_26-June-2020-FINAL.pdf (cogta.gov.za). (Accessed: 01 August 2023).

Dione, M., Masembe, C., Akol, J., et al., 2018, The importance of on-farm biosecurity: sero-incidence and risk factors of bacterial and viral pathogens in smallholder pig systems in Uganda, *Acta Tropica* 187, pp.214–221.

Doster, A.R., 1995, Skin diseases of swine, *Swine Health Production* 3(6), pp.256–261.

Gómez-Puerta, L.A., Lopez-Urbina, M.T., González, A.E., 2008, Occurrence of Moniezia expansa (Rud, 1810) Blanchard, 1891 (Cestoda: Anoplocephalidae) in domestic pig (*Sus scrofa domestica* Linnaeus, 1758) in Perú, *Veterinary Parasitology* 158(4), pp.380–381.

Gong, Q.L., Zhao, W.X., Wang, Y.C., et al., 2021, Incidence of coccidia in domestic pigs in China between 1980 and 2019: a systematic review and meta-analysis, *Parasites & Vectors* 14(1), p.248.

Greve, J.H., 2012, Internal parasites: helminths, *Diseases of Swine, 10th ed.; Zimmerman, JJ, Karriker, LA, Ramirez, A., Schwartz, KJ, Stevenson, GW, Eds*, pp.908–920.

Hale, O.M., Stewart, T.B., 1979, Influence of an experimental infection of *Trichuris suis* on performance of pigs, *Journal of Animal Science* 49(4), pp.1000–1005.

Hale, O.M., Stewart, T.B., Marti, O.G., 1985, Influence of an experimental infection of *Ascaris suum* on performance of pigs, *Journal of Animal Science* 60(1), pp.220–225.

Islam, A., Majumder, S., Anisuzzaman, R.A., Rahaman, M.S., Rahman, M.H., 2006, Incidence and pathology of ticks and lice of pigs in relation to age and management systems in Bangladesh, *International Journal of BioResearch* 1, pp.22–27.

Jufare, A., Awol, N., Tsegaye, Y., Hadush, B., Tadesse, F., 2015, Parasites of pigs in two farms with poor husbandry practices in Bishoftu, Ethiopia, *Onderstepoort Journal of Veterinary Research* 82(1), pp.1–5.

Kagira, J.M., Kanyari, P.W., Maingi, N., et al., 2010, Characteristics of the smallholder free-range pig production system in western Kenya, *Tropical Animal Health and Production* 42, pp.865–873.

Kagira, J.M., Kanyari, P.N., Githigia, S.M., et al., 2012, Risk factors associated with occurrence of nematodes in free range pigs in Busia District, Kenya, *Tropical Animal Health and Production* 44, pp.657–664.

Kagira, J.M., Kanyari, P.N., Maingi, N., et al., 2013, Relationship between the incidence of ectoparasites and associated risk factors in free-range pigs in Kenya, *International Scholarly Research Notices 2013*.

Kaufmann, J., 1996, *Parasitic infections of domestic animals: a diagnostic manual*. ILRI (aka ILCA and ILRAD).

Kouam, M.K., Ngueguim, F.D., 2022, Prevalence, intensity, and risk factors for helminth infections in pigs in Menoua, Western Highlands of Cameroon, with Some Data on Protozoa, *Journal of Parasitology Research 2022*.

Kumar, S., Prasad, K.D., Singh, S.K., 2002, Incidence of common gastrointestinal parasites in pigs at and around Ranchi, Jharkhand, *Indian Journal of Animal Sciences* 72(1), pp.35–37.

Kumsa, B., Kifle, E., 2014, Internal parasites and health management of pigs in Burayu District, Oromia Regional State, Ethiopia, *Journal of the South African Veterinary Association* 85(1), pp.1–5.

Laha, R., 2015, Sarcoptic mange infestation in pigs: An overview, *Journal of Parasitic Diseases* 39, pp.596–603.

Lapage, G., 1968, Veterinary Parasitology. 2nd edn. Oliver and Boyd, *Edinburgh and London*. Pp. 1082–1120.

Lee, S., Alkathiri, B., Kwak, D., Lee, S. M., Lee, W. K., Byun, J. W., Lee, S. H. 2022, Distribution of gastrointestinal parasitic infection in domestic pigs in the Republic

of Korea: Nationwide Survey from 2020-2021. *The Korean Journal of Parasitology*, 60(3), pp.207–211. https://doi.org/10.3347/kjp.2022.60.3.207

Matos, C., Sitoe, C., Banze, J., et al., 2011, A pilot study of common health problems in smallholder pigs in Angónia and Boane districts, Mozambique, *Journal of the South African Veterinary Association* 82(3), pp.166–169.

Munzhelele, P., 2015, *Evaluation of the production systems and constraints of smallholder pig farming in three agro-ecological zones of Mpumalanga province, South Africa* (Masters Dissertation).

Munzhelele, P., Oguttu, J., Fasanmi, O.G., Fasina, F.O., 2017, Production constraints of smallholder pig farms in agro-ecological zones of Mpumalanga, South Africa, *Tropical Animal Health and Production* 49, pp.63–69.

Munzhelele, P., Oduniyi, O.S., Scheltens, M.L., et al., 2021, Determinants of market choice and strategies adopted by small-scale pig producers in redline areas of Mpumalanga Province, South Africa: A Fractional Outcome-Tobit Model approach, *Journal of Hunan University Natural Sciences* 48(12).

Ngowi, H.A., Kassuku, A.A., Maeda, G.E.M., Boa, M.E., Willingham, A.L., 2004, A slaughter slab survey for extra-intestinal porcine helminth infections in northern Tanzania, *Tropical Animal Health and Production* 36(4), pp.335–340.

Nonga, H.E., Lugendo, F., 2015, Incidence of mange infestation in smallholder pig farms in selected areas of Mpwapwa town, Tanzania.

Nonga, H.E., Paulo, N., 2015, Incidence and intensity of gastrointestinal parasites in slaughter pigs at Sanawari slaughter slab in Arusha, Tanzania.

Nsoso, S.J., Mosala, K.P., Ndebele, R.T., Ramabu, S.S., 2000, The incidence of internal and external parasites in pigs of different ages and sexes in Southeast District, Botswana, *Onderstepoort Journal of Veterinary Research* 2000 Sep, 67(3), pp217–20.

Nsoso, S.J., Mannathoko, G.G., Modise, K.G., 2006, Monitoring production, health and marketing of indigenous Tswana pigs in Ramotswa village of Botswana.

Nwafor, I.C., Roberts, H., Fourie, P., 2019, Incidence of gastrointestinal helminths and parasites in smallholder pigs reared in the central Free State Province, *Onderstepoort Journal of Veterinary Research* 86(1), a1687. https://doi. org/10.4102/ojvr.v86i1.1687.

Odo, G.E., Agwu, E.J., Ossai, N.I.K., et al., 2016, A survey of ectoparasites of local pigs, *Sus scrofa domesticus* at Emene Town area in Enugu State, *Academia Journal of Biotechnology* 4, pp.126–137.

Omudu, E.A., Amuta, E.U., 2007, Parasitology and urban livestock farming in Nigeria: Prevalence of ova in faecal and soil samples and animal ectoparasites in Makurdi, *Journal of the South African Veterinary Association* 78(1), pp.40–45.

Ózsvári, L., 2018, Production impact of parasitisms and coccidiosis in swine, *Journal of Dairy, Veterinary and Animal Research* 7(5), pp.217–222.

Pattison, H.D., Thomas, R.J., Smith, W.C., 1980, A survey of gastrointestinal parasitism in pigs, *The Veterinary Record* 107(18), pp.415–418.

Permin, A., Yelifari, L., Bloch, P., et al., 1999, Parasites in cross-bred pigs in the Upper East Region of Ghana, *Veterinary Parasitology* 87(1), pp.63–71.

Polley, L.R., Mostert, P.E., 1980, *Ascaris suum* in Saskatchewan pigs: An abattoir survey of incidence and intensity of infection, *The Canadian Veterinary Journal* 21(11), p.307.

Roepstorff, A., Nansen, P., 1998, *Epidemiology, diagnosis and control of helminth parasites of swine* (Vol. 3). Rome: FAO.

Roesel, K., Dohoo, I., Baumann, M., et al., 2017, Prevalence and risk factors for gastrointestinal parasites in small-scale pig enterprises in Central and Eastern Uganda. *Parasitology Research*, 116, pp.335–345. https://doi.org/10.1007/s00436-016-5296-7.

Sanchez-Botija, C., Badiola, C., 1966, Presencie of the African swine pest virus in Haematopinus suis, *Bulletin-Office International des épizooties* 66, pp.699–705.

Poudel, S., 2018, *Prevalence of gastrointestinal parasites of domestic pig (Sus Scorfa Domesticus Carl Linnaeus, 1758) in two farms of Pokhara Valley* (Masters Dissertation, Department of Zoology). https://elibrary.tucl.edu.np/handle/123456789/15298.

Riyesh, T., Barua, S., Kumar, N., Jindal, N., Bera, B.C., Narang, G., Mahajan, N.K., Arora, D., Anand, T., Vaid, R.K. and Yadav, M., 2016, Isolation and genetic characterization of swinepox virus from pigs in India. Comparative Immunology, Microbiology and Infectious Diseases, 46, pp.60-65.

Soulsby, E.J.L., 1982, Helminths, arthropods and protozoa of domesticated animals, 7th edition, VetBooks.

Sowemimo, O.A., Asaolu, S.O., Adegoke, F.O., Ayanniyi, O.O., 2012, Epidemiological survey of gastrointestinal parasites of pigs in Ibadan, Southwest Nigeria, *Journal of Public Health and Epidemiology* 4(10), pp.294–298.

SPSS, 2021, IBM Corp. Released 2021, IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp.

Stata Corp. 2019, *Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC.

Stewart, B.T., Hoyt, P.G., 2006, Internal parasites of swine: in Diseases of Swine.

Symeonidou, I., Tassis, P., Gelasakis, A.I., Tzika, E.D., Papadopoulos, E., 2020, Prevalence and risk factors of intestinal parasite infections in Greek swine farrow-to-finish farms, *Pathogens* 9(7), p.556. https://doi.org/10.3390/pathogens9070556.

Tamboura, H.H., Banga-Mboko, H., Maes, D., et al., 2006, Incidence of common gastrointestinal nematode parasites in scavenging pigs of different ages and sexes in eastern centre province, Burkina Faso, *Onderstepoort Journal of Veterinary Research* 73(1), pp.53–60.

Taylor, M.A., Coop, R.L., Wall, R.L., 2015, *Veterinary Parasitology*. John Wiley & Sons.

Tomass, Z., Imam, E., Kifleyohannes, T., et al., 2013, Incidence of gastrointestinal parasites and Cryptosporidium species in extensively managed pigs in Mekelle and urban areas of southern zone of Tigray region, Northern Ethiopia, *Veterinary World* 6(7).

Urquhart, G.M., Armour, J., Duncan, J.L., et al., 2003. Veterinary Parasitology 2nd ed. Black well science Ltd.Oxford.

Vaumourin, E., Vourc'h, G., Gasqui, P., Vayssier-Taussat, M., 2015, The importance of multiparasitism: examining the consequences of co-infections for human and animal health, *Parasites and vectors* 8(1), pp.1–13. https://doi.org/10.1186/s13071-015-1167-9.

Webster, J., 2016., Animal Welfare: Freedoms, Dominions and "A Life Worth Living". Animals 6(6), 35. https://doi.org/10.3390/ani6060035.

Wilson, R.T., Swai, E.S., 2014, Pig production in Tanzania: a Critical Review, *Tropicultura* 32(1).

CHAPTER FOUR

FREE-ROAMING PIG HUSBANDRY PRACTICES IN A PERI-URBAN SETTING IN MPUMALANGA, SOUTH AFRICA.

ABSTRACT

Background: The human-animal-environment interaction has increased significantly due to globalization, increased urbanization, environmental deterioration, and the increasing need for animal-sourced foods.

Aims: This study examined peri-urban free-roaming pig (FRP) production husbandry practices, production constraints, and risks in Gert Sibande District Municipality, Mpumalanga.

Materials and Methods: A cross-sectional study design was used in this study. A snowball sampling was adopted to recruit FRP pig farmers. A total of 124 farmers volunteered and agreed to participate in the study. Cross-tabulation and correlation analysis were used to assess the relationship between categorical variables. Statistical significance was set at $\alpha = 0.05$.

Results: Peri-urban FRP farming in Gert Sibande District Municipality was dominated by men (70.2%), with only 18.4% of FRP farmers being 18–35 years old and 46.8% earning ≤ R2000 monthly, while 25% did not have a consistent income. Most (93.5%) of the farmers reared pigs without permission from the local authorities, and 72.6% did not register for animal identification. It was found that 94.35% of pig farmers did not disinfect and 87.1% were unaware of transboundary animal diseases and zoonoses. The majority of farmers (75.8%) did not adopt a weaning protocol to manage the breeding of their pigs. Most farmers reared exotic breeds or their crosses (72.5%), and most sows (51.6%) farrowed 6–10 piglets per litter. More farmers (23.4%) who reared exotic breeds or their crosses weaned >11 (large litters) in comparison to farmers who reared indigenous (17.5%) and crosses of indigenous and exotic breeds (16.7%). Moreover, only 30% of the farmers who reared exotic breeds weaned the litters at ≤ 60 days, compared to the percentage who reared other breeds. There was a positive correlation between pigs scavenging around residential areas, crossing roads, and owners not concerned with where the pigs get their feed.

Conclusion: The widespread poor husbandry practices and production indices observed among FRP farmers present opportunities to develop customized risk communication and community engagement materials for farmers and communities. Gert Sibande District Municipal Authorities should adopt a fit-for-purpose peri-urban livestock policy with clear incentives such as subsidized municipal water and state veterinary services and penalties such as fining the pig owner, impounding pigs, etc. to promote animal identification and good practices. Given the inherent risk of pigs spreading diseases to humans, good production practices have the potential to reduce the risk of disease transmission from animal-sourced food to humans.

Keywords: Pig production systems; constraints; zoonosis; scavenging; risks, pig farmers

4.1. Introduction

Recent social trends include globalization, growing urbanization, incursion into previously uninhabited environments, anthropogenic environmental degradation, increasing demand for animal-sourced foods, and rising levels of poverty. Furthermore, the resultant need for households to adopt alternative livelihood strategies, including the rearing of free-roaming pigs and other livestock in peri-urban areas, are major realities of modern times. Free-roaming pigs have significantly increased interaction between humans, domestic pigs, other livestock, and wild animals.

Poor peri-urban farmers tend to raise high fecundity and rapidly growing pigs to meet household food needs and resource security needs by contributing to the food supply for urban and peri-urban households. Between 2008 and 2017, it was estimated that 10% - 20% of the world's food supply originated directly from the urban/peri-urban agriculture (Graefe *et al*., 2008; Omondi *et al.*, 2017).

Due to the increasing competition for land resources resulting from increasing urbanization and human movements, there are fewer pastures available in peri-urban areas. Consequently, mono-gastric animals are increasingly being reared as livestock compared to ruminants (Chauhan *et al*., 2016; Mekuriaw and Asmare, 2014; Phiri *et*

al., 2003). Mono-gastric animals, such as pigs, differ from ruminants in various ways, including developing quickly, having excellent feed conversion, being simple to house and sell, needing a small amount of land for farming, having a high fecundity and protein content, being able to thrive even when free-roaming, and being adaptable to a range of climatic conditions.

The treatment provided by commercial farmers to their intensively managed pigs reflects the fact that effective pig production depends mainly on good management, which includes providing quality feeding, housing, breeding stock and biosecurity. Although pig farming in urban and peri-urban areas of some parts of South Africa is allowed, the pigs must be raised in an enclosed space (DAFF, 2024). The rearing of free roaming pigs is widely practiced in South Africa's peri-urban areas, particularly in the Mpumalanga province (Amar *et al*., 2021). According to Munzhelele *et al*. (2024), pigs raised under free roaming conditions must adapt to their environment. They are often fed dead chicken and they forage for food from the ground. In addition, swill is their main source of food, and they scavenge on sewerage and garbage sites. Unsurprisingly, pigs raised in a free-roaming setting (FRP) typically have a higher mortality rate, experience delayed growth and a low reproduction rate and are susceptible to inbreeding, caused by many of the FRP farmers providing inadequate health care, inadequate feeds, and inadequate shelter to their pigs. This is of particular concern in areas such as Mpumalanga where the risk of outbreaks of ASF is high in peri-urban areas. The high risk of transmission of diseases like ASF is due to frequent movement of people and animals in and out of the peri-urban as well as the widespread practice of feeding swill, a high number of free roaming and scavenging pigs, illegal slaughter of pigs, and trade of pig products within the community (Amar *et al*., 2021).

It is estimated that 7.8 million people in South Africa will move to cities by 2030. The National Development Plan (NDP) proposes that cities become the driving force of economic growth through increased social participation and economic efficiency. According to additional forecasts, in 2050, the proportions of people in urban/ peri-urban areas will nearly triple to 70% (United Nations, 2018). As the urban population grows, the pressure on the limited food sources will increase, there will be more intense competition for limited resources, and challenges to meeting the needs of a

healthy urban population (Mwasi *et al*., 2017). Thus, the practices of peri-urban farming and free-roam livestock is likely to grow as the human population grows.

Previous work in the peri-urban space involving FRP farming has documented inappropriate waste management, lack of water for the animals, lack of high-quality feeds, poor livestock health management, high veterinary expenses, and low output levels due to inadequate management (Guendel and Richards, 2002). To overcome these identified challenges, peri-urban pig farming must be revolutionized using appropriate farming technology, and fit-for-purpose relevant laws and regulations (Mwasi *et al*., 2017).

Therefore, this study was conducted to investigate the peri-urban FRP production husbandry practices to identify production constraints associated with FRP husbandry in Gert Sibande District Municipality of Mpumalanga province, South Africa. The findings of this study could be used to enhance FRP production in peri-urban settings, which in turn could help optimise FRP farming, thereby addressing food scarcity and providing an income to FRP farmers and their families, to help in alleviating poverty and mitigating the risks of outbreaks of diseases in the peri-urban area.

4.2. Materials and methods

4.2.1. Description of the study area

The Gert Sibande District Municipality (GSDM) is situated in Mpumalanga province. It covers 31 845,9km^2 (41% of the province land area) and, is the largest district in the province (26.5471^{o}S, 29.9741^{o}E). The district is made up of the seven municipalities, namely Chief Albert Luthuli (CALM), Msukaligwa, Govan Mbeki, Dipaliseng, Lekwa, Mkhondo and Pixley ka Seme (Figure 4.1). The GSDM is bordered by Swaziland, KwaZulu Natal province (KZN), Free State province (FS), Gauteng province (GP), Nkangala District Municipality, and Ehlanzeni District Municipality. Zulus and Swatis are the two major ethnic groups in the district.

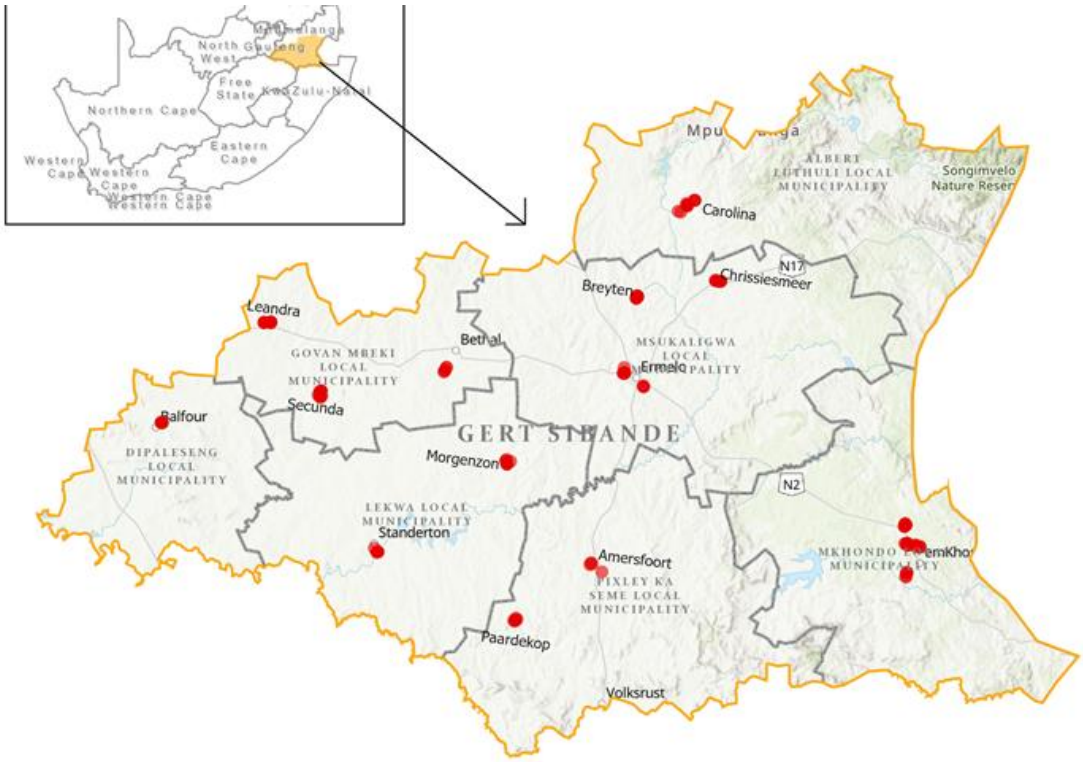


Figure 4.1: Map of the Gert Sibande District Municipality displaying seven municipalities along with the coordinates of the data collection points Source: DARDLEA Information technology.

4.2.2. Sampling and data collection

The number of pig farmers in the free-roaming pig production system in the Gert Sibande District Municipality (GSDM) is unknown. Therefore, it was not possible to develop a sampling frame and, hence, the snowball sampling approach was adopted to identify potential study participants. To cover all the peri-urban study areas, abstract transects were used to select various starting locations from which snowballing was conducted, and as many perspectives were covered along each transect. Data were collected using structured questionnaire which consisted of both open- and closed-ended questions. To ensure data consistency and to avoid repetition, ArcGIS Survey123 (https://survey123.arcgis.com/) was utilized to gather data and mapping of sampled areas. A total of 124 participants were identified who, after the study was explained to them, they read and agreed to sign an informed consent form indicating their voluntarily participation in the study.

4.2.3. Data analysis

Data were extracted from ArcGIS Survey123 and imported into Microsoft Excel®. The coding and analyses of the data were conducted in SPSS V28.0 (IBM SPSS, 2022). Descriptive statistics were displayed as percentages and frequencies for categorical variables. To examine the association between categorical variables, cross tabulation of proportions was applied. Additionally, correlation between the variables was assessed.

4.3. Results

4.3.1. Socio-economic and demographic profile of free roaming pig farmers in peri-urban areas of GSDM

A total of 124 respondent were recruited using the snowballing method. The practice of rearing peri-urban free-roaming pig (FRP) farming in Gert Sibande District Municipality was dominated by male farmers (70.2%). Very few (18.4%) people between the ages of 18 and 35 were involved in farming of FRP, while the majority of farmers were between the ages of 36 and 59. In terms of monthly income, 46.8% of the farmers earned ≤ R2000 monthly and 25% were without regular income. Approximately 42.7% of participants had high school education but did not complete matric, 25.8% had primary education, and 16.1% had no formal education and only 15.3% either had matriculated or passed grade 12. The predominant household sizes among pig farmers were 3 to 5 members (41.1%) and 6 to 10 members (40.3%) (Table 4.1).

Table 4.1: Socio-economic and demographic profile of the peri-urban free-roam pig farmers, Gert Sibande District Municipality, South Africa

Variables	Frequencies	Percentage
Gender		
Male	87	70.2
Female	37	29.8
Age (years)		
18 - 35	24	19.4
36 – 59	56	45.2
>60	44	35.5
Monthly income		
None (not regular)	31	25.0
<R1000	16	12.9
R1001 – R2000	45	33.9
R2001 – R5000	20	16.1
R5001 – R10000	10	8.1
R10001 – R20000	5	4.0
Highest level of education		
None	20	16.1
Primary	32	25.8
Secondary	53	42.7
Passed matric	16	12.9
>Diploma	3	2.4
Size of the household		
Alone	5	4.0
2	11	8.9
3-5	51	41.1
6-10	50	40.3
>11	7	5.6

Note: total number of participants (124). **Source**: Field survey

4.3.2. Attributes of free-roaming pig farming in GSDM

Farmers who reared only livestock made up the majority of study participants (58.1%), while 41.9% claimed to practice mixed farming. All pig farmers surveyed also owned other livestock such as cattle (40.3%), goats (31.5%), poultry (48.4%), sheep (4.8%), and other livestock (6.5%) in the peri-urban areas of GSDM in Mpumalanga province. (Table 4.2).

Exotic pig breeds and their crosses were the most widely reared pigs (72.6%) in the study area. Indigenous breeds were reared by only 32.3% of the respondents. On the other hand, 19.4% of the respondents reared both exotic breeds and crosses of indigenous breeds (Table 4.2).

The majority of farmers (24.2%) kept between 11 and 15 pigs, followed by those who reared between 6 and 10 (17.7%) or 21 to 30 (17.7%) pigs. As outliers, only 11.3% of the farmers kept 1 to 5 pigs and very few farmers (3.2%) kept > 51 pigs.

Just over a third (35.5%) of the study participants had no piglets on their farm at the time of the survey (Table 4.2). A total of 4.8% of the farmers reported that their sows gave birth to ≤ 5 piglets, while just over half (51.6%) indicated that their sows littered between 6-10 piglets per farrowing, followed by 43.5% who reported that their pigs farrowed >11 piglets per sow per farrowing.

With respect to weaning, most farmers (63.7%) indicated that they weaned 6–10 pigs per sow. This was followed by 21.0% who indicated that they weaned more than 11 piglets per sow, and 15.3% who weaned ≤ 5 piglets per sow. Only 44.4% of the respondents had breeding boars and the remaining 55.6% of the respondents did not have breeding boars. The majority (70.2%) of respondents had 6 to 10 breeding sows in their pig herd while only 10.5% had more than 10 breeding sows (Table 4.2).

Table 4.2: Features of free roaming pig farming in Gert Sibande District Municipality.

Variables	Frequencies	Percentage
Type of farming system practiced		
Livestock farming only	72	58.1
Mixed farming	52	41.9
Type of pig breeds		
Exotic breed & their crosses	90	72.6
Indigenous breed	40	32.3
Cross breed x indigenous breed	24	19.4
Type of livestock		
Pigs	124	100
Cattle	50	40.3
Poultry	60	48.4
Sheep	6	4.8
Goat	39	31.5
Other*	8	6.5
Number of pigs per respondent		
1 - 5	14	11.3
6 – 10	22	17.7
11 – 15	30	24.2
16 – 20	19	15.3
21 - 30	22	17.7
31 – 50	13	10.5
> 51	4	3.2
Piglets present during the survey		
Present	80	64.5
Absent	44	35.5
Number of piglets farrowed / sow		
1 – 5	6	4.8
6 – 10	64	51.6
11 – 15	53	42.7
1> 16	1	0.8
Number of piglets weaned / sow		
1 – 5	19	15.3
6 – 10	79	63.7
> 11	26	21.0
Age at weaning		
No specific weaning age	94	75.8
≤ 35 days	7	5.6
36 – 60 days	23	18.5
Breeding stock		
Breeding boars (Yes)	55	44.4
Breeding boars (No)	69	55.6
Number of breeding sows		
< 5	24	19.3
6 – 10	87	70.2
> 11	13	10.5

Note: *other includes rabbits, turkey, ducks, geese. Exotic breeds and their crosses = offspring of different exotic breeds. Crosses of exotic breed and indigenous breed = offspring of exotic breed crossed with indigenous breed. Source: Field survey.

4.3.3. Management practices adopted by FRP farmers in the peri-urban areas of Gert Sibande District Municipality

Of the 124 farmers included in the study, most (93.5%; n=116) farm pigs without any form of legal land ownership document. Of the remaining farmers, only 1.6% (n=2) claimed to have leased land from the municipality and only 4.8% (n=6) claimed they owned the land on which they reared FRPs (Table 4.3). The majority of farmers (98.4%; n=122) indicated that they housed their pigs overnight but 19.4% (n=24) could not show any form of housing available for their pigs.

Among the farmers who had housing for their pigs, the most commonly used housing material consisted of corrugated iron sheets (41.9%) erected over a soil floor (79%; n=98), over a concrete floor (19.4%; n=24) or over a wooden floor (1.6%; n=2). These figures are indicated in Table 4.3.

Most pig farmers (72.6%; n=90) did not have animal identification marks registered with the National Department of Agriculture (NDA). Those with animals that did have identification marks comprised 25% (n=31) of the study population, with the remaining 2.4% (n=3) of the study participants being unaware of the requirement for pig identification mark (Table 4.3).

Of those farmers registered with the NDA, most (21.8%; n=27) acknowledged that they had not implemented the tattooing of the pigs even though they were registered with an animal identification mark usable in South Africa. Further probes into other forms of identification revealed that 74.2% (n=92) of all study participants did not use any form of identification and 9.7% cut half of one ear of each of their pigs as a form of identification. Among all surveyed participants, only 8.1% used ear notching, ear tagging or tattooing as a way of pig identification. With respect to castration, two thirds (66.1%, n=82) of the pig farmers did not castrate male pigs that were not needed for mating purposes (Table 4.3).

Participants who indicated that they slaughtered pigs at home made up 62.9% (n=78) of the study population, while only 3.2% (n=4) claimed that they consulted the animal health professionals to examined pigs before slaughter. Participants in the GSDM involved in peri-urban free-roaming pig farming who did not know where the pigs acquired feed when they are scavenging constituted 63.7% (n=79) of the farmers

interviewed, while those who moved pigs across roadways made up 66.9% (n=83). Those who indicated that they had experienced theft of their pigs or the death of their pigs due to predation made up 69.4% (n=86) and 31.5% (n=39) of the study participants, respectively. Dogs (21.8%; n=27), jackals and other wild animals (3.2%; n=4), being beaten by people (1.6%; n=2), poisoning (1.6%, n=2), and other causes (1.6%; n=2) were mentioned as causes of loss of pigs through predation.

Most (78%; n=108) of the farmers with FRP reported that they were not aware of transboundary animal diseases (TADs). For example, very few farmers were aware of African swine fever (8.0%; n=10), Foot and Mouth Disease (0.8%; n=1), or tuberculosis (0.8%; n=1). Furthermore, 2.4% (n=1) of the farmers reported that they were aware of the TADs but were unable to recall the name of such diseases. In addition, the vast majority of farmers did not make use of disinfectants (94.35%; n=117), and those who indicated that they used disinfectants, used various disinfectants such as dip (1.6%; n=2), Jeyes fluid [(p-chloro-m-cresol (p-chlorocresol) + (Poly-) alkylphenols + Propan-2-ol (isopropyl alcohol) + Terpineol)] /Jik (sodium hypochlorite) (3.2%; n=4), and salt water (0.8%; n=1) (Table 4.3).

With respect to the age of pigs at first gestation, the majority of study participants (57.2%; n=71) claimed not to know the pig's first age of gestation. Meanwhile 25.1% (n=31) indicated first gestation at ≥12 months old and 12.1% indicated between 6 and 8 months (Table 4.3).

Table 4.3: Details of free-roaming pig farmers in Gert Sibande District Municipality

Variables	F*	%	Variables	F*	%
Type of land ownership?			**Do the pigs walk across the road?**		
Owning	6	4.8	No	41	33.1
Leasing	2	1.6	Yes	83	66.9
Farming without permission	116	93.5			
Do you house pigs overnight?			**Do you slaughter at home?**		
No	2	1.6	No	46	37.1
Yes	122	98.4	Yes	78	62.9
Type of house			**If yes, do you request state vet to perform inspection?**		
None	24	19.4	No	73	58.9
Corrugated house with roof	52	41.9	Yes	4	3.2
Fence surrounding with corrugated roof	6	4.8	Not applicable	47	37.9
Fence surrounded without roof	4	3.2			
Wood house with roof	26	21.0			
Wood surrounding with plastic roof	2	1.6			
Wood surrounding without roof	10	8.2			
Type of soil in the house?			**Do you make use of disinfectant?**		
Concrete	24	19.4	No	117	94.4
Woods	2	1.6	Yes	7	5.6
Soil	98	79.0			
Are you registered for animal identification mark?			**If you use disinfectant, what do you use?**		
No	90	72.6	Not applicable	117	94.4
Yes	31	25.0	Dip	2	1.6
I don't know	3	2.4	Jeyes fluid/Jik bleach*	4	3.2
			Water with salt	1	0.8
If you are registered, do you tattoo the pigs?			**Are you aware of any transboundary animal diseases (TADs) in pigs?**		
No	27	21.8	No	108	87.1
Yes	4	3.2	Yes	15	12.1
Not applicable	93	75.0	No data	1	0.8
How do you identify your pigs?			**If you know TADs, please specify?**		
None	92	74.2	Not applicable	109	87.0
Ear notch, tag or tattoo	10	8.1	Forgot the name	3	2.4
Tail docking	3	2.4	Foot and Mouth Disease	1	0.8
Cut half of the ear	12	9.7	African Swine Fever	10	8.0
Other	7	5.6	Tuberculosis	1	0.8
Do you know where your pigs get feed?			**If yes, have you experienced any mortality due to accident?**		
No	79	63.7		63	50.8
Yes	41	33.1	No	21	16.9
No opinion (I don't know)	3	2.4	Yes	40	32.3
Not applicable	1	0.8	Not applicable		
Do you experience mortality due to predation?			**Age at 1st gestation**		
			Unknown	71	57.2
No	85	68.5	6 – 8 months	15	12.1
Yes	39	31.5	9 – 11 months	7	5.6
			≥ 12 months	31	25.1

What causes predation in pigs)			**Do you castrate the pigs?**		
Not applicable	87	70.2	No	82	66.1
Dogs	27	21.8	Yes	42	33.9
Jackals and wild animals	4	3.2			
Dogs and beaten by people	2	1.6	**Theft experience**		
Dogs and poisoned	2	1.6	No	38	30.6
Unknown	2	1.6	Yes	86	69.4

Note: F* is Frequencies. Jeyes fluid is an outdoor cleaning fluid. Jik bleach is a detergent used to remove stains in clothes. Other: just by looking and their colour. The active ingredients in the chemical are: Jeyes fluid [(p-chloro-m-cresol (p-chlorocresol) + (Poly-) alkylphenols + Propan-2-ol (isopropyl alcohol) + Terpineol)] / Jik (Sodium Hypochlorite).

Among the free-roaming pig farmers in Gert Sibande District Municipality, the proportion of exotic breeds and their crosses that wean larger litter sizes (>11) was higher (23.4%) than that of indigenous and indigenous/exotic crosses (17.5% and 16.7%, respectively). Similarly, litters of the exotic breeds and their crosses were more likely to be weaned within 1 - 2 months (30%) compared to the litters of the indigenous and indigenous/exotic crosses at 17% and 8.4%, respectively (Table 4.4).

Table 4.4: A cross-tabulation illustrating the relationship between the breeds and total number of piglets weaned, and age at weaning in peri-urban farming

		Total number of piglets weaned		
Breeds	Number of piglets	1 – 5 piglets	6 – 10 piglets	>11 piglets
Exotic breed and their crosses	90	(n= 9) 10%	(n=59) 65.6%	(n=22) 23.4%
Indigenous breed	40	(n=8) 20.0%	(n=25) 62.5%	(n=7) 17.5%
Cross of exotic x indigenous breed	24	(n=4) 16.7%	(n=16) 66.7%	(n=4) 16.7%
			Age at weaning	
Breeds	Number of piglets	No weaning	1 – 35 days	36 – 60 days
Exotic breed and their crosses	90	(n=63) 70%	(n=6) 6.7%	(n=21) 23.3%
Indigenous breed	40	(n=33) 82.5%	(n=1) 2.5%	(n=6) 15%
Cross of exotic x indigenous breed	24	(n=22) 91.7%	(n=1) 4.2%	(n=1) 4.2%

Note: Percentages and numbers were based on respondents. a. Dichotomy group tabulated at value 1. >11 piglets = 11 piglets and above. n=number. No weaning = weaned after 61 days.

A strong positive correlation was observed between scavenging pigs and pigs walking across the roads ($r = 0.760$; $p<0.01$). A weak to moderate positive correlation existed

between mortality due to predation and scavenging pigs (r = 0.328; p<0.01) as well as pigs walking across the roads (r = 0.413; p<0.01) (Table 4.5). A very weak but positive correlation existed between pig theft and scavenging pigs (r = 0.227; p = 0.11), pigs walking across the roads (r = 0.185; p<0.04) and mortality due to predation (r = 0.191; p<0.03). Almost all evaluated variables were weakly to moderately negatively correlated, except experienced pig theft, which showed a very weak positive correlation (Table 4.5).

Table 4.5: Correlation between different variables of free roaming pigs in peri-urban areas

		Do you know where your pigs find feeds?	Do pigs walk across the roads?	Do Pigs scavenge around the dwelling areas?	Experienced pig theft?	Mortality of pigs due to predation?
Do you know where your pigs find feeds?	Pearson Correlation	1				
	Sig. (2 tailed)					
	N	124				
Does pigs walk across the roads?	Pearson Correlation	**-.500****	1			
	Sig. (2 tailed)	<.001				
	N	124	124			
Pigs scavenge around the dwelling areas?	Pearson Correlation	**-.348****	**.760****	1		
	Sig. (2 tailed)	<.001	<.001			
	N	124	124	124		
Experienced pig theft?	Pearson Correlation	-.157	.185*	.227*	1	
	Sig. (2 tailed)	.082	.039	.011		
	N	124	124	124	124	
Mortality of pigs due to predation?	Pearson Correlation	-.169	**.328****	**.413****	.191*	1
	Sig. (2 tailed)	.061	<.001	<.001	.033	
	N	124	124	124	124	124

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

4.4. Discussion

Pig production in the study area is dominated by men, which is consistent with what previous studies from the same area of Mpumalanga province (Munzhelele, 2015; Munzhelele *et al*., 2017), Gauteng (Matabane *et al*., 2015), Limpopo (Mokoele *et al.*, 2014), the Eastern Cape (Mpalala, 2022), and the Western Cape (Cupido, 2020). This could be attributed to the fact that FRP farming in peri-urban areas is labor-intensive for women since pig owners must gather swill, water or feeds from various places, and people must walk a distance to feed the pigs. However, in comparison, in Kenya, Kagira e*t al*. (2010) and Mwasi *et al*. (2017) observed that a higher proportion of females were engaged in pig farming.

In this study, a very low number of youths (18 to 35 years old) participated in peri-urban free-roaming pig practice in the Gert Sibande District Municipality. While the roles of men and women in pig farming specifically, and in livestock farming in general, have been confirmed, the continuing poor level of youth involvement in pig farming, despite the majority of the population in Africa being the youth, together with the increasing need for animal-sourced foods, is concerning (Matabane *et al*., 2015; Mpalala, 2022). However, this low participation in pig farming by young people may be attributed to the fact that a good proportion of the youth aged from 18 - 21 years are likely to be enrolled in colleges or universities and may be away for at least four years attending tertiary education. Furthermore, the few who are involved in agriculture may be involved in modern, intensive pig farming. Alternatively, it is also possible that the observation above reflects disinterest in livestock farming on the part of the youth who may be more interested in applying more modern developments such as information technologies (IT). In this regard, it may be useful to apply such interests towards livestock farming infrastructure such as feeding protocols, deliveries and logistics, record management, breeding programmes, genetics, etc. This may stimulate interest in the youth and assist in stemming their drift away from animal agriculture.

Regarding education, the majority of participants (84.6%) had either never attended school or had discontinued their secondary education. This trend has also been observed in other developing countries. For example, research from Tanzania that was conducted by Kimbi *et al*. (2015) reported similar reported.

Generally, the income levels in the study were very low as evidenced by the fact that one quarter of participants had little to no regular income at all, and 12.9% of study participants relied on a monthly wage of less than R1000, while 33.9% earned between R1001 and R2000. The minimum living wage per household in South Africa is considered to be R8935 per month (Mywage, 2024) and study results show that adding these three wage categories together indicates that 71.8% of individuals involved in FRP farming earned a regular monthly income that was well below the bare minimum amount necessary for any household to thrive in South Africa. In view of these findings, either those engaged in peri-urban pig farming in GSDM of Mpumalanga only consider FRP farming as a last resort, or have other sources of incomes that provide additional funds to meet monthly family needs. In a situation of complete dependence on peri-urban pig farming alone, farming families are not able to meet the needs of their families and properly manage their pig. This could explain why only 33.1% of all respondents in this study cared to know where their pigs get their feeds, and almost 70% allowed their pigs to walk across roads in search of sustenance at the risk of being knocked down by a vehicle. Mwasi *et al.* (2017) confirmed that peri-urban farming is a crucial activity that helps the peri-urban poor and middle class to retain their way of life in terms of additional livelihood sources and food security. Together, these underscore the need to inform existing and potential FRP farmers as to increasing their knowledge surrounding FRP farming. The application of such knowledge towards improving the housing, feeding and health of their pigs could lead to an increase in income from FRP farming to such an extent that this makes this type of farming more financially viable and so more attractive to younger farmers.

In this survey, the majority of households had 3-5 members, while 40% had 6-7 members. Given the low income for households observed in this study, there is a need for scaling up in breeding sow numbers or a modified practice (transitioning from free roam scavenging type to intensive farming) so as to increase the contribution of FRPs to the livelihood sources in the study area. However, further investments are necessary in biosecurity, housing, quality breeding stock, agricultural land, and pig management training. In view of the plan of national, provincial and local government authorities to lift the poor out of poverty, government assistance in this scaling up exercise is warranted and worthwhile.

Although the focus of this study was on FRP farming in peri-urban areas, we observed that a significant percentage of pig farmers also engaged in keeping other livestock such as cattle, poultry and goats. Similarly, studies conducted among poor communities in Botswana, Kenya and Nigeria also observed that it was common for pigs to be reared with other species in peri-urban areas (Iyayi *et al.*, 2003; Mosha, 2015; Mwasi *et al.*, 2017). However, where all these animals are reared together under a mixed-species farming and free-roaming farming setting, without any form of physical barriers, this provides an enabling environment for shared pathogens and parasites.

According to Mwasi *et al.* (2017) and Roessler *et al.* (2016), the goal of farming with diverse species of animals is to reduce the probability of being negatively impacted by disaster during disease outbreaks. While these small-scale farmers make low investment into their farming practices, they also do not have livestock insurance and so an outbreak of rapidly-spreading infectious disease such as African swine fever in pigs or highly pathogenic avian influenza or Newcastle disease in poultry may wipe out the total livelihoods of the farmers. Hence, improved farming methods such as diversification of the farmed species helps mitigate financial losses and protects farmers against sudden ruin.

Animal theft was a major problem in the peri-urban free-roaming system. This is consistent with previous findings and continues to remain a challenge among South African farmers (Molotsi *et al*., 2021; Munzhelele, 2015). Anecdotal evidence and expert opinion suggest that the Department of Agriculture, Land Reform, and Rural Development links stock theft to a lack of legal registration and use of approved animal identification marks. Animals with such approved identification are more difficult to steal and present for slaughter at approved facilities. Unfortunately, in this study, the overwhelming majority (72.6%) of the respondents claimed to not have registered for animal identification marks for their pigs.

In line with the Animal Identification Act (No. 6 of 2002), the farmer is required to submit an application for the registration of an identification mark at the Department of Agriculture, Land Reform, and Rural Development, and pigs ought to have tattoos on their bodies that serve as their animal identification marks as well as owner identity. Such animals, if stolen or lost and found, allow their easy identification along with the

owner. The Act may also need to be reviewed to see whether there are barriers that serve as disincentives for compliance by the small-scale pig farmers.

A strong link was established between theft and pigs that cross roads while scavenging for feed in residential areas (Table 4.5). This was expected given that pigs that are allowed to roam free are more likely to be stolen. In view of this, confinement of pigs is necessary, particularly in the peri-urban areas, to transition their free-roaming scavenging to more desirable intensive farming (Fualefac *et al*., 2014; Kouam *et al*., 2020; Mbuthia *et al*., 2015). The transition can be supported through the municipality and government allocating land for lease to pig farmers. In addition, farmers may access funding, particularly in Mpumalanga, where the Department of Agriculture, Rural Development, Land and Environmental Affairs (DADRLEA) administers the Masibuyele Esibayeni Programme (MESP). This initiative assists farmers from previously disadvantaged groups but who must provide land ownership, leasing agreements, or occupancy permits to qualify for assistance. The program provides qualifying farmers with quality breeding sows and boars, medication, and feed for a specified duration, along with veterinary support. Consequently, this may promote the expansion of peri-urban pig farming.

In this study, indigenous breeds were kept by relatively few farmers (32.3%). The rearing of indigenous pigs has also been observed elsewhere. For example, results of a study conducted by Motsa *et al*. (2021) reported that 26% of the surveyed respondents kept indigenous pigs. In the GSDM, one of the predominant tribes are the Zulus, and according to Gcumisa (2013), fat from indigenous breeds are applied to izidwaba (traditional Zulu women's clothing) and was also used to ward off evil spirits in infants. Hence, keeping indigenous breeds may be more for cultural purposes rather than for meat production.

The number of pigs kept per household in this study varied widely, with only 24.2% keeping 11–15 pigs and even a smaller percentage (3.2%) keeping 51 or more pigs. Comparing the results from the present study to those from the literature, 11.3% of study participants kept 1 - 5 pigs compared with 73% of Kenyan farmers who kept 1 - 3 pigs (Kagira *et al.*, 2010), while in Cameroon, 65% of farmers kept 1 - 5 pigs (Fualefac et al., 2014), and in Tanzania, 60% kept 1 - 4 pigs (Kimbi *et al*., 2015). Based on the findings reported by Halimani *et al*. (2012), the size of the pig herd is influenced

by availability of resource such as feeds according to various seasons (Chiduwa *et al*., 2008).

The majority (55.6%) of pig farmers in peri-urban free-roaming areas relied on their neighbors' boars, which can result in transmission of reproduction-related diseases such as brucellosis, porcine reproductive and respiratory syndrome and other infectious diseases such as classical swine fever. The practice also predisposes the herds to significant level of inbreeding (Kouam *et al.*, 2020; Mbuthia *et al.*, 2015; Munzhelele, 2015). Inbreeding can negatively impact weaning weight, litter size and generally reduce pig development, by promoting runting, congenital defects, and overall poor reproductive performance (Kagira *et al*., 2010). According to Muhanguzi *et al*. (2012) and Wabacha *et al.* (2004), the lack of in-farm boars is attributed to the small number of sows kept, the additional cost of keeping the boars and the poor quality breeding stock in smallholder settings. It is therefore unsustainable to keep a boar in such settings.
Results from the present study supported observations by other researchers (Mbuthia *et al*., 2015) regarding the owning of exotic breeds and their crosses that are preferred over other, including indigenous, breeds. This results from the exotic breeds showing a high fecundity, better mothering capacity contributing to a faster growth rate, leading to a high return (Guan *et al*., 2022; Mbuthia *et al*., 2015; Munzhelele *et al*., 2021).

The exotic breeds and their crosses farrow and wean more litter per sow within a shorter period compared to the indigenous breeds (Muhanguzi *et al.*, 2012; Munzhelele *et al*., 2016). However, while the exotic breeds and their crosses may appear to perform better in peri-urban settings, their adaptation and sustainability in tropical environments with their endemic diseases are limiting factors to the adoption of exotic breeds by small scale farmers (Roessler *et al.*, 2016).
There was a wide disparity in the numbers of piglets farrowed per sow and the number weaned. According to the literature, some sows may lose ≥ 60% of their piglets in free-roaming settings (Kagira *et al*., 2010; Munzhelele *et al*., 2016).

The scavenging and free-roaming characteristics of these pigs, including their crossing roads, exposes them to a number of risks including diseases and parasites (Munzhelele *et al*., 2024, 2017), theft, predation, accidents, and contact with other sick

animals. These factors all have implications regarding economic losses (Madec *et al*., 2010). Furthermore, while scavenging, pigs may access public dams, sewage, as well as contaminated carcasses, manure or urine. In exposing themselves to pathogens from such sources, they, in turn, pose additional zoonotic risks to humans (Chenais *et al*., 2019; Madec *et al*., 2010; Makovska *et al.*, 2023). In particular, predation by free-roaming dogs exposes the pigs to rabies, as reported in China, when pigs died 2 – 3 days after showing symptoms of rabies (Jiang *et al*., 2008).

Pigs are entitled to the five freedoms of Webster, and although animal cruelty is illegal according to the Animal Protection Act 71 of 1962, there have been cases documented in the GSDM. For example, with regard to housing, although the overwhelming majority of the respondents claimed to have provided some form of overnight holding pens for the peri-urban free-roaming pigs, the adequacy of those facilities is doubtful because of the materials used and the difficulty of cleaning and providing adequate heating systems (temperature control) for piglets and other such challenges (Bröde *et al*., 2013; Chiduwa *et al*., 2008, 2009; Mabuya and Scholes, 2020). Although Region and Tracy (2018) suggested that materials for pig housing should be readily available, reasonably priced, durable, flexible, and aesthetically pleasing, it is doubtful if this can be achieved since similar materials are needed for human housing needs. In the survey area, environmental temperature may go as low as -1°C in winter and above 30°C in summer, sometimes associated with snowfall, hail and severe thunderstorms.

It is possible that the low adoption of durable materials for housing are due to most peri-urban pig farmers (93.5%) not owning land and rearing pigs without permission from the municipal authorities. This state of affairs could discourage investment in housing. On the other hand, appropriate pig houses can only be put up after an environmental impact assessment (EIA) has been conducted and a certificate is obtained, to comply with various acts such as the Air Quality Act of 2004 (Act No. 39 of 2004), the Waste Act of 2008 (Act No. 59 of 2008), and the National Environmental Management Act of 1998 (Act No. 107 of 1998). However, compliance to these guidelines and Acts by smallholder farmers are somewhat challenging in view of their size of operations and average investment. Perhaps, a basic minimum, with stepwise scalable process may be a suitable guide to promote inclusiveness in compliance by smallholder farmers of peri-urban FRP.

Biosecurity in peri-urban farming requires strengthening so as to protect human and animal health. The importance of this is underscored by the fact that only 5.65% of study participants used disinfection, while most used compounds such as salted water, animal dip, Jeyes fluid and Jik (Sodium Hypochlorite). It is doubtful if the use of these mixtures complies with manufacturer's recommendations. Secondly, it is doubtful if salt-water mixtures that are employed are sufficiently concentrated to assist FRP from parasitic infestation and infection involving bacteria, fungi and viruses. Furthermore, because approximately 79% of the pig houses had soil floors, it is impracticable to disinfect such surfaces, resulting in pathogen build up and spread within the pig housing. Kimbi *et al.* (2015) reported soil floors in 44.6% of the pig housing in their Tanzanian investigation while Motsa'a *et al*. (2021) reported soil floors in 42.2% of pig housing in their Cameroonian study. In addition, implementing biosecurity is challenging and near impossible among free-roaming pigs. The ongoing outbreaks of ASF in Mpumalanga and other provinces attest to this fact (Amar *et al*., 2021). In addition, farmers lack the knowledge of disease control, a gap that the Extension and Veterinary services of the Department of Agriculture, Rural Development, Land and Environmental Affairs must investigate (Food and Agriculture Organization, 2008; Kouam *et al*., 2020; Singh *et al.*, 2023).

4.5. Conclusion

Although rearing FRPs has the potential to contribute to the livelihood of farmers, it is presently underperforming. However, its reorganization has great potential to mitigate poverty, improve food security and strengthen household income. To facilitate this revival, certain government Acts and policies on peri-urban animal husbandry need to be urgently improved to provide specific guidance in this sector to improve biosecurity, and human and animal health. The municipality must allocate land for farmers and promote the confinement of pigs, mandate registration with DAFF for animal identification, and implement a penalties policy for non-compliance to these rules and regulations. These measures will foster increased production and adherence to official regulations in the Gert Sibande District Municipality of Mpumalanga province. From a business and marketing perspective, it would be useful to establish pig study groups and cooperatives to facilitate purchasing in bulk and sales. This might have a knock-on advantage of attracting younger farmers in FRP farming in the peri-urban space. The low level of biosecurity uptake among the farmers and the inherent risk of outbreak

of disease of economic and public health importance, coupled with the observed illegal slaughter of pigs is a serious public health concern that relevant authorities need to take into consideration when developing policies to manage the sector. Training of pig farmers on significant zoonotic diseases that are of public concern.

4.6. References

Amar, S., De Boni, L., de Voux, A., Heath, L., Geertsma, P., 2021. An outbreak of African swine fever in small-scale pigs, Gauteng, South Africa, July 2020. International Journal of Infectious Disease 110 Suppl 1, S44–S49. https://doi.org/10.1016/j.ijid.2021.04.003

Bröde, P., Krüger, E.L., Fiala, D., 2013. UTCI: Validation and practical application to the assessment of urban outdoor thermal comfort. Geographia Polonica 86, 11–20. https://doi.org/10.7163/GPol.2013.2

Chauhan, A., B.H.M., P., Maurya, R., Kumar, Sushil, Shukla, S., Kumar, Subodh, 2016. Pig production system as a source of livelihood in Indian scenario: An overview 5, 2089–2096.

Chenais, E., Lewerin, S.S., Boqvist, S., Ståhl, K., Alike, S., Nokorach, B., Emanuelson, U., 2019. Smallholders' perceptions on biosecurity and disease control in relation to African swine fever in an endemically infected area in Northern Uganda. BMC Veterinary Research 15, 279. https://doi.org/10.1186/s12917-019-2005-7

Chiduwa, G., Chimonyo, M., Halimani, T.E., Chisambara, S.R., Dzama, K., 2008. Herd dynamics and contribution of indigenous pigs to the livelihoods of rural farmers in a semi-arid area of Zimbabwe. Tropical Animal Health and Production 40, 125–136. https://doi.org/10.1007/s11250-007-9071-8

Cupido, M., 2020. An insight into the livelihood of small-scale pig farmers in the Western Cape, South Africa (PhD Thesis). Stellenbosch: Stellenbosch University.

DAFF, 2024. Guidelines for Urban and Peri-urban Animal Agriculture. Available at: https://old.dalrrd.gov.za/docs/AAPS/Urban_animal_Agri.pdf. (Accessed: 27 February 2024).

Food and Agriculture Organization, 2009. Farmers Handbook on Pig Production for the Small Holders at Village level. Rome Italy.

Food and Agriculture Organization, 2008. Biosecurity for Highly Pathogenic Avian Influenza: Issues and Options, FAO Animal Production and Health Paper. Food and Agriculture Organization of the United Nations, Rome.

Fualefac, D.H., Raphae, K.J., Bime, M.J., Ndebi, G., Yemele, F., Zoli, P.A., Manjeli, Y., Teguia, A., Tchoumboue, J., 2014. Socioeconomic and technical characteristics of pig farming in the urban and peri-urban zone of Dschang-West region of Cameroon. Discourse Journal of Agriculture and Food Sciences 2, 11–20.

Gcumisa, S.T., 2013. The untold story of the pig farming sector of rural KwaZulu-Natal: A case study of Uthukela District (PhD Thesis). University of South Africa.

Graefe, S., Schlecht, E., Buerkert, A., 2008. Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. Outlooks in Agriculture 37, 47–56. https://doi.org/10.5367/000000008783883564

Guan, R., Zhou, X., Cai, H., Qian, X., Xin, X., Li, X., 2022. Study on the influence of different production factors on PSY and its correlation. Porcine Health and Management 8, 9. https://doi.org/10.1186/s40813-022-00253-2

Guendel, S., Richards, W., 2002. Peri-urban and urban livestock keeping in East Africa-a coping strategy for the poor. Scoping study commissioned by the DFID Livestock Production Programme.: Natural Resources Institute.

Halimani, T.E., Muchadeyi, F.C., Chimonyo, M., Dzama, K., 2012. Opportunities for conservation and utilisation of local pig breeds in low-input production systems in Zimbabwe and South Africa. Tropical Animal Health and Production 45, 81–90. https://doi.org/10.1007/s11250-012-0177-2

IBM SPSS [WWW Document], 2022. Available at: https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-28. (Accessed: 27 February 2024).

Iyayi, E.A., Okoruwa, V.O., Babayemi, O.J., Busari, A.A., Peters, O.E., 2003. Livestock production pattern of agropastoralists in peri-urban centres of south-west Nigeria. Nigerian Journal of Animal Production 30, 87–92.

Jiang, Y., Yu, X., Wang, L., Lu, Z., Liu, H., Xuan, H., Hu, Z., & Tu, C. (2008). Short report. An outbreak of pig rabies in Hunan province, China. Epidemiology and Infection, 504–508(136), https://doi:10.1017/S0950268807008874.

Kagira, J.M., Kanyari, P.W.N., Maingi, N., Githigia, S.M., Ng'ang'a, J.C., Karuga, J.W., 2010. Characteristics of the smallholder free-range pig production system in western Kenya. Tropical Animal Health and Production 42, 865–873. https://doi.org/10.1007/s11250-009-9500-y

Kimbi, E., Lekule, F., Mlangwa, J., Mejer, H., Thamsborg, S., 2015. Smallholder pigs production systems in Tanzania. Journal of Agricultural Science and Technology A 5, 47–60.

Kouam, M.K., Jacouba, M., Moussala, J.O., 2020. Management and biosecurity practices on pig farms in the Western Highlands of Cameroon (Central Africa). Veterinary Medicine and Science 6, 82–91. https://doi.org/10.1002/vms3.211

Mabuya, B., Scholes, M., 2020. The three little houses: A comparative study of indoor and ambient temperatures in three low-cost housing types in Gauteng and Mpumalanga, South Africa. International Journal of Environmental Research and Public Health 17, 3524.

Madec, F., Hurnik, D., Porphyre, V., Cardinale, E., 2010. Good practices for biosecurity in the pig sector: Issues and options in developing and transition countries.

Makovska, I., Dhaka, P., Chantziaras, I., Pessoa, J., Dewulf, J., 2023. The role of wildlife and pests in the transmission of pathogenic agents to domestic pigs: A Systematic Review. Animals 13, 1830.

Matabane, M.B., Nethenzheni, P., Thomas, R., Netshirovha, T.R., Norris, D., Nephawe, K.A., Nedambale, T.L., 2015. Status of the smallholder pig farming sector in Gauteng Province of South Africa. Applied Animal Husbandry & Rural Development 8, 19–25.

Mbuthia, J.M., Rewe, T.O., Kahi, A.K., 2015. Evaluation of pig production practices, constraints and opportunities for improvement in smallholder production systems in Kenya. Tropical Animal Health and Production 47, 369–376. https://doi.org/10.1007/s11250-014-0730-2

Mekuriaw, Y., Asmare, B., 2014. Assessment of pig production and constraints in Mecha district, Amhara region, Northwestern Ethiopia. Advances in Agriculture 2014.

Mokoele, J.M., Spencer, B.T., Van Leengoed, L.A.M.G., Fasina, F.O., 2014. Efficiency indices and indicators of poor performance among emerging small-scale pig farmers in the Limpopo Province, South Africa. Onderstepoort

Journal of Veterinary Research 81, 12 pages. https://doi.org/10.4102/ojvr.v81i1.774

Molotsi, A.H., Cupido, M., Hoffman, L.C.H., 2021. Characterization of smallholder pig production systems in the Western Cape, South Africa. Tropical Animal Health and Production 53, 325. https://doi.org/10.1007/s11250-021-02649-8

Mosha, A.C., 2015. Urban agriculture in Botswana. Commonwealth Journal of Local Governance 48–67.

Motsa'a, J.S., Defang, H.F., Hako, T.B.A., Ojong, E.T., Mube, K.H., Nguekem, C.L., 2021. Socioeconomic and productive characteristics of indigenous pig farming in Cameroon. Rural Development 14.

Mpalala, N., 2022. The effects of pig farming on unemployment alleviation in Buffalo City, Eastern Cape (PhD Thesis). Cape Peninsula University of Technology.

Muhanguzi, D., Lutwama, V., Mwiine, F.N., 2012. Factors that influence pig production in Central Uganda-Case study of Nangabo Sub-County, Wakiso district.

Munzhelele, P., 2015. Evaluation of the production systems and constraints of smallholder pig farming in three agro-ecological zones of Mpumalanga province, South Africa (PhD Thesis).

Munzhelele, P., Oduniyi, O.S., Scheltens, M.L., Antwi, M., Christian, M., Fasina, F.O., 2021. Determinants of market choice and strategies adopted by small-scale pig producers in redline areas of Mpumalanga Province, South Africa: A Fractional Outcome-Tobit Model approach. Journal of Hunan University Natural Sciences 48.

Munzhelele, P., Oguttu, J., Fasanmi, O.G., Fasina, F.O., 2017. Production constraints of smallholder pig farms in agro-ecological zones of Mpumalanga, South Africa. Tropical Animal Health and Production 49, 63–69. https://doi.org/10.1007/s11250-016-1158-7

Munzhelele, P., Oguttu, J.W., Fasina, F.O., 2016. Is a 10-sow unit economically sustainable? A profitability assessment of productivity amongst small-holder pig farmers, Mpumalanga, South Africa. Onderstepoort Journal of Veterinary Research 83, 11 pages. https://doi.org/10.4102/ojvr.v83i1.1011

Munzhelele, P., Sibeko, N.P.S., Oguttu, J.W., Mbajiorgu, C.A., Fasina, F.O., 2024. Parasites burden in peri-urban free-roaming pigs in Gert Sibande District

Municipality of Mpumalanga province, South Africa. Journal of the South African Veterinary Association 95, 3–12. https://doi.org/10.36303/JSAVA.601

Mwasi, G.M., Jung, J.O., Mbugua, P.N., Kinama, J.M., Okello, G.O., 2017. The contribution of urban and peri urban livestock farming in Nairobi county, Kenya. Journal of Agriculture and Veterinary Science 10, 26–42.

Mywage, 2024 [WWW Document]. WageIndicator Foundation. Available at: https://mywage.co.za/salary/cost-of-living-survey/living-wage (Accessed: 22 January 2024).

Omondi, S.O., Oluoch-Kosura, W., Jirström, M., 2017. The role of urban-based agriculture on food security: Kenyan case studies. Geographical Research 55, 231–241. https://doi.org/10.1111/1745-5871.12234

Phiri, I.K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., 2003. The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. Acta Tropica 87, 13–23.

Region, W., Tracy, K., 2018. The effect of housing systems on the welfare of pigs in santa sub-division in the North West region of Cameroon. Journal of Environmental Issues and Agriculture in Developing Countries 10, 24–25.

Roessler, R., Mpouam, S.E., Muchemwa, T., Schlecht, E., 2016. Emerging development pathways of urban livestock production in rapidly growing West Africa cities. Sustainability 8, 1199.

Singh, M., Pongener, N., Mollier, R., Paton, R., Yadav, R., Katiyar, R., Mishra, V., 2023. Participatory assessment of management and biosecurity practices of smallholder pig farms in North East India. Frontiers in Veterinary Science 10. https://doi.org/10.3389/fvets.2023.1196955

United Nations, 2018, World Urbanization Prospects: The 2018 Revision. Available at: https://population.un.org/wup/publications/Files/WUP2018-KeyFacts.pdf. (Accessed: 22 January 2024).

Wabacha, J.K., Maribei, J.M., Mulei, C.M., Kyule, M.N., Zessin, K.H., Oluoch-Kosura, W., 2004. Characterisation of smallholder pig production in Kikuyu Division, central Kenya. Preventive veterinary medicine 63, 183–195.

CHAPTER FIVE

PROXIMATE ANALYSIS OF DIFFERENT SWILL FED TO FREE-ROAMING PIGS IN PERI-URBAN AREAS OF GERT SIBANDE DISTRICT MUNICIPALITY IN MPUMALANGA PROVINCE, SOUTH AFRICA

ABSTRACT

Background: Feeding pigs on leftovers from households, restaurants, hotels, bakeries, food processing facilities, fruit and vegetable markets, and other locally accessible sources is common practice. However, there is no evidence of studies that have investigated the composition of swill fed to pigs in Gert Sibande District Municipality (GSDM).

Aim: To investigate the composition of the different swills and how swill can be reconstituted to meet the nutrient requirements for FRPs in peri-urban areas of GSDM.

Material and methods: A total of 14 swill samples of different types of swill (Household, School, Restaurant and Wholesaler) were collected from the storage bins of pig producers in peri-urban areas of GSDM. The samples were analyzed specifically for Moisture, DM, CP, ADF, CF, Ca, Na, P, Ash and pH. A mean comparison was conducted, and the proportions of categorical variables were computed using the SPSS, v2022. $P<0.05$ was decided on as the cut off p-value.

Results: The Household Swill (HS) (80.14%) and School Swill (SS) (80.27%) had a higher moisture content in comparison to the Restaurant Swill (RS) (54.36%) and Wholesaler Swill (WS) (56.63%). The DM content for HS (19.86±8.21 g/kg DM) and SS (19.73±6.94 g/kg DM), was low, while the DM content for RS (45.65±27.57 g/kg DM) and WS (43.37±25.45 g/kg) was relatively high. The Ca content of RS (28.91±11.28 g/kg DM) was two times higher than the Ca content for SS (14.92±12.79 g/kg DM). The SS and RS had the highest concentrations of Na (8.52±3.44 g/kg DM) and P (11.30±0.99 g/kg DM) in comparison to the other swill types. In terms of ash and pH, SS had the highest ash content (11.28±8.98%), while WS had the highest pH (5.38±0.58%).

Conclusion: The levels of the different nutrients in each swill were either higher or lower than the average required for feeding the pigs of different ages. Therefore, in order to sufficiently balance and maintain the nutritional needs of pigs that depend on

swill as their main source of nutrient, the swill would need to be supplemented with other feed types or various types of swill could be combined. For example, a suitable diet for piglets and weaners could be formulated by combining WS and HS that would balance the low nutritional value of the HS. Likewise, for growing pigs, a suitable diet could potentially be developed through combining the SS and RS. In addition, the SS could potentially supply the required nutrients for the finishers and breeding pigs as its nutrient composition will be able to support their health and production, including growth, milk and reproduction requirements.

Keywords: Swill feeding, swill types, nutrient composition, pig nutrition, diet, feed formulation, proximate analysis

5.1. Introduction

Pig nutrition is a significant issue in pig farming since feed expenses account for between 70% and 80% of overall production costs. This is particularly true in cases where pigs are fed commercial feeds. This is because primary feed ingredients are expensive and, moreover, animals and humans compete for the same sources of feed ingredients (Kanengoni *et al*., 2015; Wadhwa and Bakshi, 2013). The problem of climate change exacerbates the situation, by causing lower grain growth rates, which lead to a 15% loss in grain and disruptions in the food supply chains (Kim and Lee, 2023). Likewise, the problem of wars ravaging nations is contributing to increases in prices of food for both humans and animals (World Economic Forum, 2024). This pushes pig producers to feed their pigs on economically viable items with an unknown nutrient content, such as leftover food from various sources (swill).

Several studies from different countries have reported feeding swill to pigs (Chae *et al.*, 2000; Petrus *et al.*, 2011; Mokoele *et al.*, 2014; Birungi *et al.*, 2015; Matabane *et al.*, 2015; Munzhelele *et al*., 2016; Lule *et al.*, 2017; Muthui *et al.*, 2019). In addition, there are reports of pigs being fed rotten maize, hominy chops, coarse maize meal, maize husks, green maize, vegetables, pumpkins, watermelons, fruits, grasses, and brewer's waste in the place of costly conventional feed products (Madzimure, 2011; Ncobela *et al.*, 2017).

The bulk of the swill originates from leftovers from households, restaurants, hotels, bakeries, food processing facilities, fruit and vegetable markets, and other locally accessible sources (Katongole *et al.*, 2012; Tekle *et al*., 2013; Munzhelele, 2015; Chauhan *et al.*, 2016; Lule *et al.*, 2017; Munzhelele *et al.*, 2017). The availability of swill in South Africa is promoted by the fact that up to 1.6 billion tons of food goes to waste or goes uneaten every day across the country (Stats SA, 2023). Food waste levels have been driven by changes in lifestyle, particularly in urban and peri-urban areas. Here, food leftovers are foods that were produced in full compliance with food laws for human consumption but are no longer meant for human consumption due to manufacturing issues, packaging errors, or other defects – thus, these foods do not pose a health risk when used as feed (Gustavsson, 2011; Jong *et al.*, 2019). However, according to the European commissioner (2013), food leftovers that have deteriorated or are contaminated, should not be added to the animal feed chain. In addition, the product needs to have adequate nutritional content to qualify as feed.

Pigs, like all other animals, require feed to extract the nutrients necessary to support their health, including growth, milk and reproduction. However, in contrast to other animals, pigs require different feeds in terms of nutrient composition based on their age. As pigs gain weight, their requirements for the majority of nutrients drops. As a result, the composition of feeds must be changed in order to fulfil their nutritional needs. These different nutritional needs are impacted by their physiological status, potential for performance, and environmental factors (National Research Council, 1998). However, when swill is used as feed for pigs, a homogeneous swill content is provided to all age groups without taking into consideration the varying nutritional needs of the various age groups of pigs (Lemke *et al.*, 2007). Swill has been noted to be composed of high amounts of carbohydrates and inconsistent nutritional qualities (Kagira *et al.*, 2010; Katongole *et al.*, 2012; Mutua *et al.*, 2012; Beyihayo, Mwesigwa and Pezo, 2015). A balanced diet is essential to meet the nutritional requirements for the pig to promote its growth to its maximum capacity.

There is little published information regarding the nutritional value and chemical composition of different kinds of food waste as well as how they could potentially be used to feed pigs. To address this, proximate analysis of swill is crucial to evaluating the swill nutrient composition to ensure that pigs receive a balanced diet and the

proper amount of each nutrient. Therefore, this study was conducted to investigate the composition of the different swills and how swill can be reconstituted to meet the nutrient requirements for FRPs in peri-urban areas of GSDM in Mpumalanga province, South Africa.

5.2. Materials and methods

5.2.1. Study site

The study was carried out in seven municipalities within the Gert Sibande District Municipality of the Mpumalanga Province (Figure 5.1). As of 2017, all seven municipalities in the district had significant rates of poverty, varying between nearly 35% to nearly 60% (COGTA, 2020): Govan Mbeki (34.6%), Lekwa (39.7%), Dipaliseng (42.4%), Msukaligwa (42.9%), Chief Albert Luthuli (50%), Pixley ka seme (56.1%), and Mkhondo (59.9%).

The study sites were peri-urban areas located close to the town. As a result, farmers can easily obtain swill from a variety of swill resources, including market places, restaurants, and wholesalers.

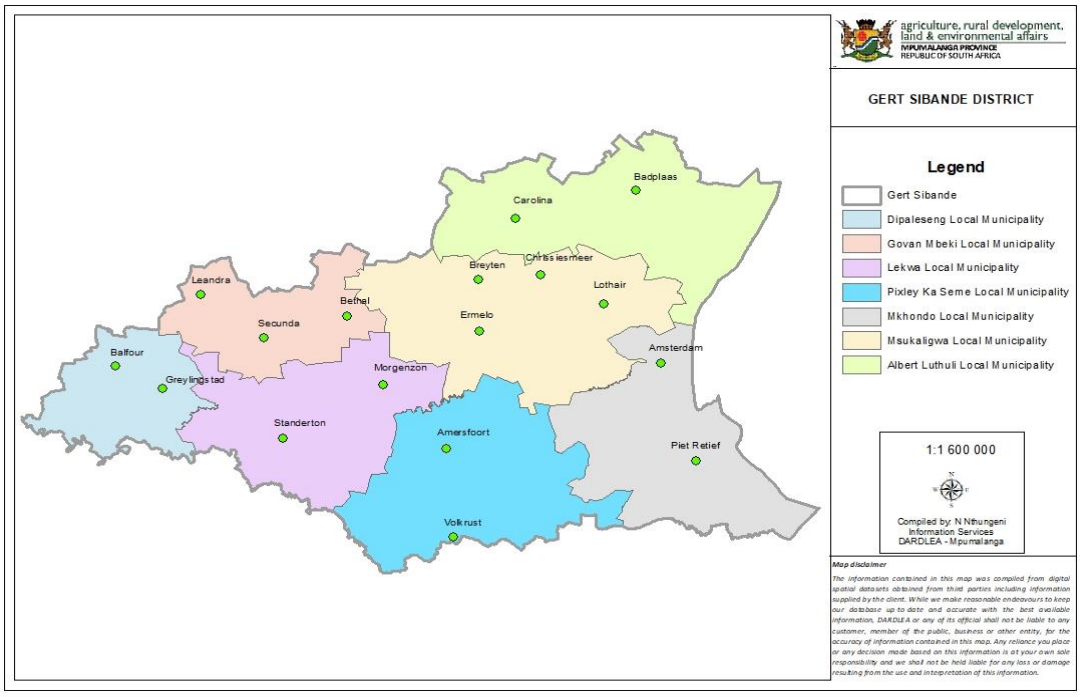


Figure 5.1: Map of the Gert Sibande District Local Municipality Source: Technology Transfer (DARDLEA) in Nooitgedacht Research Farm

5.2.2. Data collection

Swill samples were collected directly from the barrels used by the pig producers for storing swill. Systematic random sampling procedures, which were initially intended for this investigation, could not employed due to similarities of the swill used by several participants. As a result, samples of swills were collected using a purposeful sampling method, to be able to collect different varieties of swill. A total of 14 swill samples were collected from the storage bins of the free-roaming pig producers in peri-urban areas of GSDM. These were characterized as follows: household swill (HS) (n=3), school swill (SS) (n=4), restaurant swill (RS) (n=3), and wholesaler swill (WS) (n=4). The swill was first well mixed in the storage barrel prior to sample collection. The swill sample was then stored in a cooler bag with ice packs, before being transported to Nooitgedacht Research Farm on the day of collection. Observations regarding the handling of swill was also documented. In addition, during swill collection, a brief questionnaire was administered to collect information on the type of swill, the method of swill treatment employed by the participants, the duration of swill storage prior to usage, and whether the pig producer weighed the swill before feeding.

5.2.3. Proximate composition analysis

Wet samples of each swill were weighed, labelled, dried for 36 hours at 65°C in an air oven, cooled using desiccators, and then recorded as prescribed by the Association of Analytical Chemists procedures (AOAC International, 1995). The dried samples were ground, weighed and recorded. These dried samples were then sent for analysis at the University of Free State (Department of Animal, Wildlife and Grassland Sciences) for proximate composition analysis. The samples were analyzed specifically for Crude protein (CP), Acid-detergent fibre (ADF), Crude Fat (CF), Calcium (Ca), Sodium (Na), Potassium (P), Ash and potential of hydrogen (pH). The samples were analysed as follows: CF and Ash (AOAC International, 1995), CP (Kirmse, 1983), ADF (Goering and Soest, 1970), Ca (Price, 1973), Na (Poluektov, 1961), P (Cavell, 1955), and pH (Skoog *et al.*, 2013). The percentage moisture (M%) and percentage dry matter (DM%) were computed using the formula below (Proximate Analysis, 2024): Moisture percentage (%) was the weight loss that occurred when a sample was dried in an oven to a consistent weight. The moisture content was computed as follows:

Dry Matter (DM) % = 100 - Moisture%

5.2.4. Statistical analysis

The proximate composition of the analyzed laboratory data were entered into a Microsoft Excel spreadsheet, version 2016 (Microsoft Corporation, Redmond, Washington, USA). The data were ultimately loaded into the Statistical Package for Social Science and analyzed (IBM SPSS, 2022). A mean comparison was conducted in order to compare the proximate composition of the different types of swill collected in the peri-urban study area in GSDM. Furthermore, the proportions of categorical variables were computed with a significant value set at $P<0.05$.

5.3. Results

The proximate composition of the different swill types are shown in Table 5.1. The HS (80.14%) and SS (80.27%) types had the highest moisture content, followed by WS (56.63%) and RS (54.36%). Although both the RS (54.36%) and WS (56.63%) types had the lowest moisture contents, based on the standard deviation (SD), the two swill types, RS (SD=±27.57) and WS (SD=±25.45), exhibited the highest variation in terms of moisture content.

The HS (19.86, 8.21%) and SS (19.73±6.94%) types had a very low DM content, while the RS (45.65 ±27.57%) and WS (43.37± 25.45) types had a higher DM content. Based on the SD, there was a noticeable variance between all four swill types, with HS (SD=±8.21) and SS (SD=±6.94) having low SDs, while RS (SD=±27.57) and WS (SD=±25.45) having high SDs. This implies that there was significant variation in DM content among the four swill types.

At 129.05 ±28.87 g/kg DM, the HS type showed the lowest CP level, while the WS had the highest recorded CP at 387.07 ±41.34 g/kg DM, followed by RS with a CP content of 236.13 ±80.25 g/kg DM and SS with 160.95 ±32.40 g/kg DM. However, there was considerable variation in the CP content of the swill types with, for example a SD of ±80.25 g/kg DM for RS and ±41.34 g/kg DM for WS (Table 5.1).

Table 5.1: Nutritional composition of swill types collected in GSDM

Proximate principle	Household swill	School swill	Restaurant swill	Wholesaler swill
Moisture %	80.14±8.21	80.27±6.94	54.36±27.57	56.63±25.45
DM %	19.86±8.21	19.73±6.94	45.64±27.57	43.37±25.45
CP g/kg DM	129.05±28.87	160.95±32.40	236.13±80.25	387.07±41.34
ADF g/kg DM	102.16±7.55	101.81±5.25	84.84±6.58	240.96±39.90
CF g/kg DM	73.63±39.64	75.81±24.88	167.50±90.23	198.92±84.56
Ca g/kg DM	3.14±0.85	14.92±12.79	28.91±11.28	8.14±2.82
Na g/kg DM	2.47±0.42	8.52±3.44	4.07±0.39	1.11±1.06
P g/kg DM	2.14±0.2	5.82±3.55	11.30±0.99	5.80±0.64
Ash %	3.36±0.36	11.28±8.98	9.50±1.75	7.02±3.01
pH	4.5±0.46	4.8±0.32	4.68±0.4	5.38±0.58

Note: All data in this table are presented in mean ± standard deviation, DM = Dry Matter, CP = Crude Protein, ADF = Acid-detergent fibre, CF = Crude Fat, Ca = Calcium, Na = Sodium, P = Phosphorus, Ash = Total Inorganic Matter, pH = potential of hydrogen, % = percentage, g/kg = gram per kilogram, Household swill = household leftovers, School swill = school leftovers, Restaurant swill = Restaurant leftovers, Wholesaler swill = Wholesaler leftover / expired feeds.

Regarding acid detergent fibre (ADF) analysis, both the HS 102.16 (±7.55) g/kg DM and SS 101.81 (±5.25) g/kg DM types showed the lowest ADF values while the WS type showed the highest ADF (240.96 g/kg DM) and the highest SD (±39.90 g/kg DM).

In terms of crude fat (CF), the RS and WS types showed the highest CF content at 167.50 (±90.23) g/kg DM and 198.92 (±84.56) g/kg DM, respectively. However, both showed a high SD of ±84.56 g/kg DM and ±90.23 g/kg DM for RS and WS, respectively, meaning that both swill types exhibited a very high variation of the CF content.

The SS (14.92±12.79 g/kg DM) and RS (28.91±11.28 g/kg DM) showed the highest Ca content. However, the Ca content of RS was twice that of SS. Furthermore, the SD of Ca content of the two swill types was similar. Of all the swill types, the SS had the highest concentration of Na (8.52 ±3.44 g/kg DM), while the RS had the highest concentration of P (11.30 ±0.99 g/kg DM). On the other hand, the SS recorded the highest figures for Ash at 11.28% and the WS type showed the highest pH (pH = 5.38).

Swill was mostly stored in plastic barrels (84.7%; n=105), with FRP farmers also using both plastic and steel barrels (12.1%; n=15) $p< 0.001$. Of the pig producers surveyed, the majority (56.6%; n=70/124) stated that the swill was fed within 4–7 days of collection, and an additional 2.4% indicated the use of this pig feed only after 7 days. Relatively few participants fed the swill to their pigs on the same day that the swill was collected (37.1%; n=46) or within two to three days of collection (4.0%; n=5) (Table 5.2).

When asked how they handled the swill before feeding, the majority of the respondents (92.7%; n=115/124), stated that they fed the swill in the form that it was collected (i.e., they did not do anything to the swill). Only 3.2% (n=4/124) and 3.2% (n=4/124) of respondents, indicated that they first rinsed the swill with water and removed any objects. All the pig producer interviewed in this study indicated that they did not weigh the swill before feeding (Table 5.2).

Table 5.2: Swill management in peri-urban free-roaming pig farming

Variable	Level	Frequency (n)	Proportion (%)
How is swill stored before feeding?			
	Plastic barrel	105	84.7
	Steel barrel	4	3.2
	Plastic and steel barrel	15	12.1
After how long is the swill fed after collection?			
	Same day	46	37.1
	2 – 3 days	5	4.0
	4 – 7 days	70	56.5
	>7 days	3	2.4
How do you treat the swill before feeding?			
	None	115	92.7
	Rinse with water	4	3.2
	Remove unwanted objects	4	3.2
	No data	1	0.8
Do you weigh the swill before feeding?			
	No	124	100
	Yes	0	0
Additional things fed to pigs			
	Maize	7	19.4
	Dead chickens	3	8.3
	Maize and vegetables	5	13.9
	Maize and soya beans	10	27.8
	Soya beans, Sorghum (brewery)	4	11.1
	Vegetables, milk, Bran, Bread & fruits	7	19.4

Note: Maize and soya beans were soaked in water overnight

Nearly 30% (29.03%; n=36) of the farmers indicated that they provided feed additives to their pigs. Some of these farmers (27.8%; n=10) fed soybeans and maize that had been soaked in water overnight. Additives also included maize that was soaked in water overnight before being fed to the pigs, as reported by 19.4% (n=7) of the farmers, while 8.3% (n=3) said that they fed dead chickens to the pigs. Only 13.9%

(n=5) of these pig farmers indicated that they fed their pigs on vegetables and maize. In addition, feeding soya beans and sorghum were mentioned by 11.1% (n=4) of the farmers, while vegetables, milk, brans, bread and fruits were also added to the pig diet, as mentioned by 19.4% (n=7) of the farmers.

5.4. Discussion

The nutritional values of the four swill types collected and analysed in this study showed significant variation. For example, although all of the samples studied had high levels of moisture content, the HS (80.14 ±8.21%) and the SS (80.27 ±6.94%) had the highest moisture content but a low CP content of 129.057 ±28.87 g/kg DM for HS and 160.95 ±32.40 g/kg DM for the SS types. However, RS (54.36±27.57%) and WS (56.63±25.45%) exhibited a moderate level of moisture, which corresponded to a high CP content of 236.13 ±80.25 g/kg DM for RS and 387.07 ±41.34 g/kg DM for the WS types.

The variation in nutrient content between the different swill types was expected since swill is not a standardized product, and its nutritional value varies depending on a number of parameters, including the presence or absence of elements that are desirable, unwanted, or even toxic, including an excessive concentration of salt and detergent or fragments of glass (Bartel *et al.*, 1942). Other studies have reported that wet swill had a lower CP content compared to dried swill (Castrica *et al*., 2018; Asar *et al*., 2018). This observation is worth noting because in the present study, all the participants fed wet swill to their pigs. Mousa *et al*. (2018) reported that wet swill samples with a CP content of 24% or 17.4%, increased to 27.6% and 31.3%, respectively, following drying.

A high moisture content in swill significantly affects its nutrient concentration and may fill the intestine. As a result, it is important to consider this when predicting pig feed intake (Ncobela *et al.*, 2017). In addition, legislation mandates that the swill be boiled for at least an hour before being fed to pigs so as to eliminate pathogens that can cause potentially fatal diseases in the pigs. If water is added to assist in the boiling process, this will also contribute to the high moisture content in swill. From a logistical perspective, swill with an excessively high moisture content makes its transportation and storage more challenging (Westendorf *et al.*, 1999; Fung, 2019).

Findings of the present study revealed that HS (19.86%) and SS (19.73%) types showed an extremely low DM content. This is expected because as the moisture content of the feed increases, the DM decreases (Cherian, 2020). The DM content for HS and SS was well below the required level for DM in pig feeds. It is recommended that the DM should make up 90% of a pig's entire diet (National Research Council, 1998). The amount of DM in the ingredients influences the nutrient concentrations. However, the DM content is usually extremely low in several cases where alternate or readily accessible diets are administered. For example 30% of the DM was reportedly present in municipal swill (Bartel *et al.*, 1942) and 17.11% for supermarket waste, and 9.50% for fruits and vegetable waste (Fung, 2019). The results of this study demonstrated that the level of DM in HS (19.86%) and in SS (19.73%) types was significantly lower than the expected or prescribed dietary content.

Beyihayo et al. (2015) reported that pigs that consumed less DM showed a decrease in their growth rate. Thus, DM is crucial and the concentration of DM in the feed should not be less 200 g/kg DM (Brooks *et al*., 2001). The HS and SS types analysed in the present study showed a DM content of 19.86 g/kg and 19.73 g/kg, respectively, which were below the 200 g/kg DM (20%) threshold. Furthermore, these authors emphasized that providing a dietary concentration of at least 250 g/kg (25%) DM improve performance after the weaning period. Given that, the DM content in both HS (19.86%) and SS (19.73%) was below 25%, the lower limit of DM content promoting a positive impact on performance after weaning. As a result, data in the present study suggests that both HS and SS swill were unsuitable for post-weaning pig feeding.

The dry matter for RS (45.64 ±27.57%) observed in this study exceeded the reported RS level of 35.85% in Indonesian restaurants (Widayati *et al.*, 2019) and 27.00% (Westendorf *et al.*, 1999). Bartel *et al.* (1942) reported that hotels, restaurants, and the defense department produced swill of exceptional quality. Similarly, our study revealed remarkable nutritional advantages for the swill from wholesalers, especially in terms of CP and DM. Our findings placed the swill from restaurants in second place in terms of nutrient content.

Researchers have reported that feeding pigs on wet swill offers some potential advantages over dry swill. However, several studies have also documented unfavorable aspects of feeding pigs on wet swill. Enhancing the nutritional value and

beneficial microorganisms in swill are some of the benefits of feeding swill as this facilitates improved gastrointestinal health, efficient nutrient absorption, adaptability, and convenient administration (de Lange and Zhu, 2012; Cullen *et al.*, 2021). Nevertheless, feedings pigs exclusively on swill may sometimes induce gastrointestinal and respiratory complications (Beyihayo *et al*., 2015). Despite knowing about these concerns, swill still remains the most often used feed source for pigs globally (Katongole *et al.*, 2012; Tekle *et al*., 2013; Munzhelele, 2015; Chauhan *et al.*, 2016; Lule *et al.*, 2017; Munzhelele *et al.*, 2024).

The CP content relative to the dry mass levels of the WS type (387.07 g/kg; DM = 38.707%) and RS type (236.12 g/kg; DM=23.61%) were raised compared to published reported (Myer *et al*., 1999; Nayak, 2013; Westendorf *et al.,* 1999). In addition, the CP content of WS observed in this study exceeded the levels reported in other studies by a significant amount (Westendorf *et al.*, 1999; Chae *et al.*, 2000; NRC, 2012, 2012; Lange, 2014; Fung *et al.*, 2019). The SS type showed a lower CP content of 160.95 g/kg DM, corresponding to a CP level of 16.095%, comparable to what was observed in Kenyan commercial feed that ranged from 11.53 to 16.66% (Muthui *et al.*, 2019). To feed pigs with a high concentration of CP, allowing them to metabolize extra protein and use it as an energy source, this presents the challenge to prepare combinations of swill types collected from the GSDM that may then be mixed in varying proportions in an attempt to improve the ratio of the various components of swill and thereby the quality of poorer quality swill types.

According to Onsongo *et al.* (2018), the protein source is the primary factor contributing to the high cost of animal feed, as it is the most expensive ingredient. Commercial corporations may decrease the protein content in animal feeds as a cost-cutting measure due to the intense competition for protein sources between humans and animals, as well as the limited availability of protein sources due to climate change (Kanengoni *et al*., 2015; Wadhwa and Bakshi, 2013; World Economic Forum, 2024). Research has indicated that lowering the amount of dietary CP in animal feed might help ease the negative effects of high-protein diets, such as more nitrogen loss and higher feed costs (Hinson *et al.,* 2009; Presto Åkerfeldt *et al.,* 2019; Lynegaard *et al.,* 2021). Feeds with higher levels of CP result in the inefficient use of nutrients and lead to the release of excessive amounts of nitrogen into the environment (Presto Åkerfeldt

et al., 2019). In such a scenario, the practice of feeding WS could have a significant impact on triggering and increasing nitrogen emissions, mostly because of its high proportion of CP.

The crude protein (CP) content recommended for feeding, finishing and breeding pigs is 16% (Nayak, 2013). This study revealed a high level of CP content in WS (387.07 g/kg DM) and RS (236.13 g/kg DM), corresponding to 38.7% CP and 23.6% CP content, respectively. Such high levels of CP could have negative implications for pig development, overall health, and the environment. Putting pigs on a high CP diet during their weaning and growth stages has been linked to a number of problems, including the growth of bad gastric bacteria, diarrhoea, and intestinal diseases (Gao *et al.*, 2020; Yin *et al.*, 2021; Rodrigues *et al.*, 2022; Marchetti *et al.*, 2023). Undigested food with a high CP content might cause an increase in intestinal permeability and promote the proliferation of harmful bacteria (Moeser *et al*., 2017; Gao *et al.*, 2020). Additionally, it might contribute a significant buffering ability, leading to an increase in the pH of the digestive tract (Partanen and Mroz, 1999). Our findings revealed a high concentration of CP in the WS (387.07 g/kg DM), with an acidic pH of 5.38%. Both of these could make the intestinal pH higher, as reported by Partanen *et al*. (1999).

On the other hand, according to Presto Åkerfeldt *et al.* (2019), pigs fed on feeds with a high CP content experience faster growth throughout the early stages of development compared to the later stages. On the other hand, inadequate protein content in the feed results in impaired growth, which in turn leads to higher fat accumulation in the carcass. Many pig farmers often encounter this issue during the slaughtering process (Beyihayo *et al*., 2015). Interestingly, Kumar (2020) stated that a pig's diet, which includes protein sources from both animals and vegetables, provides all the necessary amino acids in appropriate quantities.

Pigs have to be fed according to their age groups; young pigs are fed with a high concentration of CP, and this should gradually be reduced as they mature. This is because CP is an essential component that promotes muscle growth and is necessary for healthy pig growth. In view of this, farmers who entirely depend on swill as a source of nutrients for their pigs will find WS and RS as being the most appropriate for

nourishing piglets due to their higher CP level, while HS and SS can be advantageous for fully-grown pigs due to their moderate CP level.

According to Nayak (2013), pigs that consume diets containing 0.2% (20 g/kg DM) crude fat (CF) achieve a desirable weight and accumulate a moderate level of body fat. Remarkably, the range of all four samples in this study exceeded the allowable CF limit, ranging from 7.3% to 19.8% (equivalent to 73.6 g/kg to 198.92 g/kg DM). A high amount of fat and salt in the feed leads to the production of soft pork, which is considered undesirable and quickly becomes rancid (Kornegay *et al.*, 1965; Matlock *et al.*, 1984; Myer *et al*., 1999; Murto *et al*., 2004; Kumar, 2020). Furthermore, high fat and salt content in feeds alter the taste characteristics could potentially introduce adverse effects to the pork, and excess salt may precipitate salt poisoning (Suttle, 2010; Georganas *et al*., 2020). However feeds with a higher fat content have a higher number of calories per unit of weight and provide essential fatty acids, thereby increasing energy levels and improving taste (Duponte, 2024). This illustrates that swill with a high fat content encourages increased consumption and acceptance by the pigs.

As indicated, all swill types in this study showed CF levels that exceeded the minimum requirement of 0.2%. Swill or food waste with a high CF content, with the exception of fruit and vegetable waste (FVW), which had a lower fat content of 1.29% (Myer *et al*., 1999; Westendorf *et al.,* 1999; Chae *et al.,* 2000; Fung, 2019). Thus, adding fruits and vegetables to the swill combination can assist in attaining a well-balanced CF content.

The Ca concentration in HS was determined to be 3.14 ±0.85 g/kg DM, or 0.314%. This concentration was lower than the calcium nutritional requirement for all pig age groups. Therefore, pigs that are fed exclusively on HS may encounter several health issues. For example, calcium or phosphorus deficiencies can lead to rickets in growing pigs, while osteomalacia can cause deformities such as lameness and bending of the long bones in young pigs, as well as fractures and posterior paralysis in older pigs (Gary, 2015). However, the SS, RS and WS types contained Ca nutrient levels that were higher than necessary for all age groups of pigs, with 14.92 ±12.79 g/kg DM (1.49%), 28.91 ±11.28 g/kg DM (2.89%) and 8.14 ±2.82 g/kg DM (0.81%), respectively.

In terms of P, the HS type showed a concentration of 2.14 ±0.2 g/kg DM (0.21%), which was below the nutritional requirements of all pig age groups. According to Nayak (2013), the required P levels for breeding pigs and finishers are 0.5%, for developing pigs it is 0.4%, and for pig starter creep it is 0.6% (see Appendix 6.1). For the SS and WS types, the respective P levels of 5.82 ±3.55 g/kg DM (0.58%) and 5.80 ±0.64 g/kg DM (0.58%) were considered to be sufficient for finishers and breeding sows, who require 0.50% and 0.4% of the P, respectively. The RS had the highest proportion of P at 11.30 ±0.99 g/kg DM (1.13%), which is twice the amount of P required for all age groups. Ca and P are important minerals required in all feed formulations for pigs of all age groups (NRC, 2012). These two essential elements are required for pigs' teeth and bones to grow and remain preserved. Pigs with deficient amounts of Ca and P may demonstration osteoporosis and an increased susceptibility to fractures, both of which can negatively affect the animal's overall performance and survival rate.

Regarding Na content of the swill types, the HS (2.47 =±0.42 g/kg DM, or 0.24%), WS (1.11 ±1.06 g/kg DM, or 0.11%) and RS (4.07 ±0.39 g/kg DM, or 0.4%) showed a significantly low Na content, falling below the minimum requirement of 5 g/kg DM or 0.5% for the different age groups of pigs. According to Chittavong *et al*. (2013) and Gary (2015), pigs on a low Na diet experience delayed and inefficient growth, resulting in poor hair and skin conditions. Suttle (2010) reported that a low Na level in pig feeds leads to an increase in the duration between oestrus and weaning in sows, as well as a decrease in appetite. In addition, Chittavong *et al*. (2013) recorded a decrease in water consumption when pigs were fed diets with low Na levels. Gary (2015) reported observing that pigs lacking Na consumed the urine of other pigs. Published reports indicated a low sodium level in swill, with values of 0.02% (NRC, 2012), 0.09% (National Research Council, 1998), and 0.35% in DRFW1 (Myer *et al*., 1999). However, from a nutritional point of view, swill with a modest amount of Na content can be easily supplemented compared to swill with an excessive Na concentration. Therefore, the generally low level of Na in the HS and WS types points to their safety from a nutritional viewpoint.

In contrast to the above Na analysis results, the SS type revealed a high Na content level of 8.52 ±3.44 g/kg DM, or 0.85%, which exceeds the acceptable level of 5 g/kg DM or 0.5% for pig feed. It is considered dangerous to consume or feed too much Na

in the diet, as it can lead to significant health problems (Suttle, 2010), and may even result in salt poisoning (Georganas *et al.*, 2020). A diet that has a large amount of Na leads to the production of pork that is soft, which buyers consider to be unsatisfactory (Kornegay *et al.*, 1965; Matlock *et al.*, 1984; Murto *et al*., 2004). To ensure that pork production meets quality standards and has a long shelf life, it is important to incorporate a well-balanced sodium content into the diets of pigs of different age groups. Therefore, in view of the findings reported in this study, caution is needed when feeding pigs using the SS type. Alternatively, due to its normally elevated Na concentration, one should approach the use of SS with caution or consider supplementation with feed that has a lower Na content.

Results of this study revealed that the ADF ranged from 8.48% to 24.09%. Specifically, HS, SS, and RS had ADF values of 10.21%, 10.18%, and 8.48%, respectively. Consequently, the ADF content in all the three swill types, did not meet the dietary nutrition standards for pigs, as shown by (Crissey *et al.*, 2001). The increased digestibility of the feeds causes the ADF content to decrease.

Regarding the acid detergent fibre (ADF) analysis, the WS type showed an ADF content of 24.09%, which is significantly higher than the optimum nutritional content range of 13–18% (Crissey *et al.*, 2001). Increased levels of ADF and NDF in feed ingredients result in decreased amino acid digestibility (Duponte, 2024). According to Kornegay *et al.* (1965), when the ADF concentration increases, the digestibility values for fat, DM, energy, and CP decline. Thus, the elevated level of ADF in the WS type could potentially affect the breakdown of essential nutrients (Kornegay *et al.,* 1965). One possible explanation for this phenomenon is that certain farmers incorporate agricultural waste or byproducts, such as cereals, grains, and residues, vegetables and legumes, such as soybeans, into pig feed. These ingredients are believed to be high in fibre and poorly digestible, making it unsuitable for use by non-ruminants and contribute approximately 20–35% of the ADF (Villas-Bôas *et al*., 2002).

The ash concentration in feed is a reliable measure of its mineral content and plays an important role in maintaining microbe stability. Both the RS (9.50%) and WS (7.02%) swill types included in this study met acceptable nutritional requirements for ash for all the pig age groups. On the other hand, the ash content of the HS type

(3.36%) fell below the nutritional threshold of 8.0% required for pig feeds across several age groups. However, the ash level of all the four swill types was lower than 25.31% and 18.07% that has been reported for swill by Chae *et al.* (2000) and Kamaruddin et al. (2020), respectively.

When compared to the other low-quality swill types and the acceptable nutritional standard, the SS type showed a higher ash concentration (11.28%). Given that 92.7% (n=115) of the study participants reported that they did not treat the swill before feeding, it is possible that soil or other contaminants introduced during swill collection could have contributed to the elevated ash level in this particular swill type. Another factor that could have contributed to the increased ash content in SS is the storage of the feeds in steel barrels, which can cause corrosion and rust formation to affect the feeds. Ash, when present in high concentrations in animal feeds, may hinder nutrient availability because animals are unable to metabolize it (Duponte, 2024). Our findings showed that while both the RS and WS contents met the necessary ash content level for feeding pigs of all age groups, the ash content in SS was highly elevated.

All the samples in our investigation had pH levels ranging from 4.5 to 5.38. *Brooks et al*. (2001) reported that when the pH of food exceeds 4.5, fermentation favors the presence of pathogens such as *Salmonella*. In fact, studies by Merrell and Camilli (2002) and Missotten *et al.* (2015) showed that harmful bacteria such as *E. coli* and *Salmonella* spp. are unable to thrive in environments with pH values below 4.5. Therefore, based on this, the pH level of the feeds should be lower than 4.5. The higher pH level above 4.5 observed for swill in this study puts the pigs that are fed on such swill as feed, at risk for pathogenic bacterial infections involving these bacteria. This may particularly be the case for weaned pigs, where there is often insufficient production of stomach acid.

Regarding swill management by the FRP farmers, the soybeans and maize were soaked in water overnight before being fed (Table 5.2). Immersing this combination for twenty-four hours leads to a significant proliferation of lactic acid bacteria, resulting in a beneficial increase in the acidity of the feed (Brooks *et al*., 2001). In contrast to the pH level of 6.5 reported by Kamaruddin *et al*. (2020), the present study findings suggest that the swill included in this study had a lower pH level ranging from 4.5 to

5.38. Unfortunately, there is a scarcity of research on the feed pH levels suitable for the various age groups, necessitating further evaluation.

In this study, 19.4% of the additional feed provided to the pigs consisted of brewer's grain. Beyihayo *et al*. (2015) pointed out that brewers' grain had a high CP content of 27.5% and a P content of 0.51%. This demonstrates that the brewer's grain possesses the capacity to fulfil the nutritional needs of the pigs at every stage of development, particularly for the piglets. However, in the case of maturing pigs, it will be necessary to dilute it in order to decrease the CP content.

Several peri-urban areas are experiencing a significant decrease in the pig population due to the ongoing outbreak of African swine fever and other pandemic diseases. One of the measures that the government has introduced to control some of the diseases is the requirement to boil swill before it is fed to the pigs. However, 92.7% of study participants stated that they did not believe it was necessary to treat the swill before feeding. According to the Animal Diseases Act, 1984 (Act No. 35 Of 1984), it is necessary to reduce the transmission of pandemic diseases by subjecting swill to treatment before feeding it to pigs. However, heating fermented swill that has aged for over four days can be difficult due to increased fermentation, especially in hot climes. Furthermore, heat treatment of feed ingredients results in a modification of their structure through the Maillard process, rendering a portion of the digestible amino acids inaccessible for protein synthesis (Pahm *et al*., 2009). According to our findings, a small percentage (3.2%) of respondents rinsed the swill with water, which is not considered an effective strategy for eradicating pathogens or germs. Prior to feeding, none of the participants expressed adherence to the Animal Disease Act of 1984, which requires the heating of swill before feeding.

Conventional feeds typically provide a daily ration of 2-3 kg to pigs, depending on their age and developmental stage. Nevertheless, all the participants in this study expressed that they did not measure the amount of swill before feeding it to the pigs. However, available evidence suggests that pigs fed with swill typically received 7.5 kg (range: 5.1–10.5 kg) on average, of feed per day (Lule *et al.*, 2017). The insufficient DM content of swill as demonstrated by the low DM for HS and SS could be a possible

explanation for high consumption of swill. As a result, pigs consume four times the normal quantity of feeds to acquire the necessary nutrients.

In addition, during the study, it was evident that unsterilized and dirty barrels were used for swill storage. Pigs that consume soil may have difficulty chewing the feeds because of the mixture of soil and food. Furthermore, consistent usage of unsterilized feeders can result in the proliferation of unwanted pathogens and the development of an unpleasant odor. Moreover, it was observed that there is a correlation between the occurrence of conditions like Coccidiosis and certain feeding practices, including feeding dead chickens, using feeders without proper cleaning, and feeding pigs from the soil floor (Munzhelele *et al.*, 2024).

As was shown in Table 5.2, 27.8% of the participants indicated that they fed the pigs a combination of maize and soybeans to supplement swill diets. The National Research Council (1998) reported that pig diets mostly consist of maize and soybean meal, which together constitute approximately 97.5% of the whole diet. Mineral supplements and carrier mixes, which include vitamins, trace minerals, and additives, make up the remaining 2.5%. The maize and soybean meal had similar digestible energy (DE) levels. Any combination of these two components will result in a highly energized diet.

Differences in nutritional contents of pig diets between countries are likely caused by variations in environmental conditions, soil types, and geographic locations. To align with local feeding preferences, the composition of swill also varies accordingly. In South Africa, a primary food source is porridge, made from ground maize. The nutritional composition of the HS type was determined to be inferior to that of other swill samples. This may be due to variation in the perceived value of swill types, which are influenced by the living conditions of the houses from which the swill was gathered. Consequently, there will be an increased quantity of porridge in the HS types. Thus, the four swill types included in this investigation had distinct nutritional compositions because they originated from different locations or settings, thereby explaining the variations in nutrient content (Kornegay *et al.*, 1965; Myer et al., 1999).

The poor quality of feed given to pigs significantly reduces their productivity in small-scale settings (Ncobela *et al.*, 2017). When adopting swill as feed, it is crucial to ensure that it is safe for consumption, free of pesticide residues or foreign substances, and it is sourced from a trustworthy supplier. Finally, well-managed swill can generate substantial profits for disadvantaged and emerging pig farmers, enabling them to more effectively farm FRP to, in turn, better handle the issues of food security and hunger linked to unemployment and poverty.

5.5. Conclusion

This study revealed significant variance among the four swill types. All of the swill samples contained a low DM content and higher moisture content. This leads to pigs needing to consume a larger quantity of feed to achieve the required DM% intake. This can be corrected by encouraging farmers to dry or dehydrate the swill. Swill as feed, has the potential to significantly influence pig farming, particularly in small-scale farming where feed expenses are high. However, as the nutrient content of swill may be outside the required levels, this necessitates their improvement by either supplementation or taking measures to ensure that excessive intake of nutrients such as proteins and Na is avoided. To provide an appropriate diet for piglets and weaners, one might produce a blend of high and low nutritional composition by combining types similar to HS and WS. A combination of SS and RS to develop a formulation that is a potentially acceptable diet for developing pigs should be encouraged. The SS type proved to be suitable as feed for finishing and breeding pigs. In general, the nutritional composition of the HS type is inferior to that of other swill types. Therefore, future studies should focus on examining the growth performance of pigs fed various types of swills. Further research is required to evaluate the quality of pork from pigs fed with the various swill types under peri-urban free-roaming conditions.

5.6. References

Animal Diseases Act, 1984 (Act No. 35 Of 1984), SAHPRA. Available at: https://www.sahpra.org.za/document/animal-diseases-act-1984-act-no-35-of-1984/. (Accessed: 21 March 2024).

AOAC International, 1995. Official methods of analysis of AOAC International. AOAC International, Arlington, Va.

Asar, E., Raheem, H., Daoud, J., 2018. Using dried leftover food as nontraditional feed for Muscovy duck diet.

Bartel, L.H., Oosthutzen, S.A., Bartel, L.H., Oosthutzen, S.A., 1942. Swill as pig feed. Farming in South Africa 17, 373–374; 408.

Beyihayo, G., Mwesigwa, R., Pezo, D., 2015. Pig feeding strategies: Uganda smallholder pig value chain capacity development training manual.

Birungi, R., Ouma, E., Dorresteijn, D., Kawuma, B., Smith, J., 2015. Uganda smallholder pig value chain capacity development training manual: Marketing and institutional strengthening.

Brooks, P., Beal, J., Niven, S., 2001. Liquid feeding of pigs: potential for reducing environmental impact and for improving productivity and food safety. Recent Advances in Animal Nutrition in Australia 13, 49–63.

Castrica, M., Tedesco, D.E.A., Panseri, S., Ferrazzi, G., Ventura, V., Frisio, D.G., Balzaretti, C.M., 2018. Pet food as the most concrete strategy for using food waste as feedstuff within the European context: A feasibility study. Sustainability 10, 2035. https://doi.org/10.3390/su10062035

Cavell, A.J., 1955. The colorimetric determination of phosphorus in plant materials. Journal of the Science of Food and Agriculture 6, 479–480. https://doi.org/10.1002/jsfa.2740060814

Chae, B.J., Choi, S.C., Kim, Y.G., Kim, C.H., Sohn, K.S., 2000. Effects of feeding dried food waste on growth and nutrient digestibility in growing-finishing pigs. Asian-Australasian Journal of Animal Sciences 13, 1304–1308.

Chauhan, A., B.H.M., P., Maurya, R., Kumar, Sushil, Shukla, S., Kumar, Subodh, 2016. Pig production system as a source of livelihood in Indian scenario: An overview 5, 2089–2096.

Cherian, G., 2020. A guide to the principles of animal nutrition (p. 163). Corvallis, OR, USA: Oregon State University.

Chittavong, M., Jansson, A., Lindberg, J.E., 2013. Effects of high dietary sodium chloride content on performance and sodium and potassium balance in growing pigs. Tropical Animal Health and Production 45, 1477–1483. https://doi.org/10.1007/s11250-013-0385-4

Cooperative Governance & Tradition Affairs., 2020. Profile analysis district development model. Gert Sibande District Municipality, Mpumalanga Province. Available at: https://www.cogta.gov.za/ddm/wp-

content/uploads/2020/07/Final-Edited-Gert-Sibande-DM_26-June-2020-FINAL.pdf. (Accessed: 30 March 2024).

Crissey, S., Dierenfeld, E.S., Kanselaar, J., Leus, K., Nijboer, J., 2001. Okapi (*Okapia Johnstoni*) SSP feeding guidelines. Silver Spring, MD: American Association of Zoos and Aquariums.

Cullen, J.T., Lawlor, P.G., Cormican, P., Gardiner, G.E., 2021. Microbial quality of liquid feed for pigs and its impact on the porcine gut microbiome. Animals (Basel) 11, 2983. https://doi.org/10.3390/ani11102983

de Lange, C., Zhu, C., 2012. Liquid feeding corn-based diets to growing pigs: Practical considerations and use of co-products. pp. 63–80. https://doi.org/10.3920/978-90-8686-756-1_3

Duponte M.W., 2024. Livestock feed analysis. Available at: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/livestock_feed_analysis.pdf. (Accessed: 30 March 2024).

European commissioner, 2013. Commission Regulation (EU) No. 68/2013 on the Catalogue of feed materials. | UNEP Law and Environment Assistance Platform [WWW Document]. Available at: https://leap.unep.org/en/countries/eu/national-legislation/commission-regulation-eu-no-682013-catalogue-feed-materials. (Accessed: 14 March 2024).

Fung, C.F.L., 2019. Nutritional Value and Benefits of Food Waste as Potential Feed Ingredients in Swine Diets (Master's thesis, University of Minnesota).

Fung, L., Urriola, P.E., Baker, L., Shurson, G.C., 2019. Estimated energy and nutrient composition of different sources of food waste and their potential for use in sustainable swine feeding programs. Translational Animal Science 3, 359–368. https://doi.org/10.1093/tas/txy099

Gao, J., Yin, J., Xu, K., Han, H., Liu, Z., Wang, C., Li, T., Yin, Y., 2020. Protein level and infantile diarrhea in a postweaning piglet model. Mediators of Inflammation 2020, e1937387. https://doi.org/10.1155/2020/1937387

Gary L. Cromwell, 2015. Nutritional diseases of pigs - management and nutrition [WWW Document]. MSD Veterinary Manual. Available at: https://www.msdvetmanual.com/management-and-nutrition/nutrition-pigs/nutritional-diseases-of-pigs. (Accessed: 30 March 2024).

Georganas, A., Giamouri, E., Pappas, A.C., Papadomichelakis, G., Galliou, F., Manios, T., Tsiplakou, E., Fegeros, K., Zervas, G., 2020. Bioactive compounds in food waste: A review on the transformation of food waste to animal feed. Foods 9, 291. https://doi.org/10.3390/foods9030291

Goering, H.K., Soest, P.J.V., 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). U.S. Agricultural Research Service.

Grain., 2024. Grain SA. Available at: https://www.agriseta.co.za/wp-content/uploads/2021/02/Grain.pdf. (Accessed: 14 March 2024).

Gustavsson, J., 2011. Global food losses and food waste: Extent, causes and prevention : study conducted for the international congress “Save Food!” at Interpack 2011 Düsseldorf, Germany. Food and Agriculture Organization of the United Nations.

Hinson, R.B., Schinckel, A.P., Radcliffe, J.S., Allee, G.L., Sutton, A.L., Richert, B.T., 2009. Effect of feeding reduced crude protein and phosphorus diets on weaning-finishing pig growth performance, carcass characteristics, and bone characteristics. Journal of Animal Science 87, 1502–1517. https://doi.org/10.2527/jas.2008-1325

IBM SPSS [WWW Document], 2022. Available at: https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-28. (Accessed: 27 February 2024).

Jong, J. de, Kleter, G., Banach, J., Raamsdonk, L. van, Hoogenboom, R., Nijs, M. de, Fels-Klerx, I. van der, Kok, E., Slot, M., Bouwmeester, H., Noordam, M., 2019. Hazards associated with animal feed. FAO.

Kagira, J.M., Kanyari, P.W.N., Maingi, N., Githigia, S.M., Ng’ang’a, J.C., Karuga, J.W., 2010. Characteristics of the smallholder free-range pig production system in western Kenya. Tropical Animal Health and Production 42, 865–873. https://doi.org/10.1007/s11250-009-9500-y

Kamaruddin, M., Jantira, N., Alrozi, R., 2020. Food waste quantification and characterization as a measure towards effective food waste management in university. IOP Conference Series: Materials Science and Engineering 743, 012041. https://doi.org/10.1088/1757-899X/743/1/012041

Kanengoni, A.T., Chimonyo, M., Ndimba, B.K., Dzama, K., 2015. Potential of using maize cobs in pig diets — A review. Asian-Australas Journal of Animal Science 28, 1669–1679. https://doi.org/10.5713/ajas.15.0053

Katongole, C.B., Nambi-Kasozi, J., Lumu, R., Bareeba, F., Presto, M., Ivarsson, E., Lindberg, J.E., 2012. Strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS) 113, 165–174.

Kim, K.-H., Lee, B.-M., 2023. Effects of Climate Change and Drought Tolerance on Maize Growth. Plants (Basel) 12, 3548. https://doi.org/10.3390/plants12203548

Kirmse, W., 1983. Organic Elemental Analysis: Ultramicro, Micro, and Trace Methods. Elsevier Science.

Kornegay, E.T., Vander Noot, G.W., Barth, K.M., MacGrath, W.S., Welch, J.G., Purkhiser, E.D., 1965. Nutritive value of garbage as a feed for swine. i. chemical composition, digestibility and nitrogen utilization of various types of garbage. Journal of Animal Science 24, 319–324. https://doi.org/10.2527/jas1965.242319x

Kumar, D.K., 2020. Nutrient requirements in Poultry, Swine & Equine. Available at: https://www.basu.org.in/wp-content/uploads/2020/04/Nutrient-requirements-in-Poultry-Swine-Equine.pdf. (Accessed: 26 March 2024).

Lange, C., 2014. New NRC (2012) Nutrient Requirements of Swine.

Lemke, U., Kaufmann, B., Thuy, L.T., Emrich, K., Zárate, A.V., 2007. Evaluation of biological and economic efficiency of smallholder pig production systems in North Vietnam. Tropical Animal Health and Production 39, 237–254. https://doi.org/10.1007/s11250-007-9001-9

Lule, P.M., Ojakol, J.F., Asindu, M., Naziri, D., Ouma, E., 2017. 1 International Livestock Research Institute (ILRI), Uganda 2 Makerere University, Uganda 3 International Potato Center (CIP), Uganda.

Lynegaard, J.C., Kjeldsen, N.J., Bache, J.K., Weber, N.R., Hansen, C.F., Nielsen, J.P., Amdi, C., 2021. A very low CP level reduced diarrhoea and productivity in weaner pigs, but no differences between post-weaning diets including soybean meal or soy protein concentrate were found. Animals 11, 678. https://doi.org/10.3390/ani11030678

Madzimure, J., 2011. Climate change adaptation and economic valuation of local pig genetic resources in communal production systems of South Africa.

Marchetti, R., Faeti, V., Gallo, M., Pindo, M., Bochicchio, D., Buttazzoni, L., Della Casa, G., 2023. Protein content in the diet influences growth and diarrhea in weaning piglets. Animals 13, 795. https://doi.org/10.3390/ani13050795

Matabane, M.B., Nethenzheni, P., Thomas, R., Netshirovha, T.R., Norris, D., Nephawe, K.A., Nedambale, T.L., 2015. Status of the smallholder pig farming sector in Gauteng Province of South Africa. Rural Development 8.

Matlock, R.G., Terrell, R.N., Savell, J.W., Rhee, K.S., Dutson, T.R., 1984. Factors affecting properties of raw-frozen pork sausage patties made with various NaCl/phosphate combinations. Journal of Food Science 49, 1363–1366. https://doi.org/10.1111/j.1365-2621.1984.tb14991.x

Merrell, D.S., Camilli, A., 2002. Acid tolerance of gastrointestinal pathogens. Current Opinion in Microbiology 5, 51–55. https://doi.org/10.1016/S1369-5274(02)00285-0

Missotten, J.A., Michiels, J., Degroote, J., De Smet, S., 2015. Fermented liquid feed for pigs: an ancient technique for the future. Journal of Animal Science and Biotechnology 6, 4. https://doi.org/10.1186/2049-1891-6-4

Moeser, A.J., Pohl, C.S., Rajput, M., 2017. Weaning stress and gastrointestinal barrier development: Implications for lifelong gut health in pigs. Animal Nutrition 3, 313–321. https://doi.org/10.1016/j.aninu.2017.06.003

Mokoele, J.M., Spencer, B.T., van Leengoed, L.A.M.G., Fasina, F.O., 2014. Efficiency indices and indicators of poor performance among emerging small-scale pig farmers in the Limpopo Province, South Africa. Onderstepoort Journal of Veterinary Research 81. https://doi.org/10.4102/ojvr.v81i1.774

Munzhelele, P., 2015. Evaluation of the production systems and constraints of smallholder pig farming in three agro-ecological zones of Mpumalanga province, South Africa.

Munzhelele, P., Oguttu, J., Fasanmi, O.G., Fasina, F.O., 2017. Production constraints of smallholder pig farms in agro-ecological zones of Mpumalanga, South Africa. Tropical Animal Health and Production 49, 63–69. https://doi.org/10.1007/s11250-016-1158-7

Munzhelele, P., Oguttu, J.W., Fasina, F.O., 2016. Is a 10-sow unit economically sustainable? A profitability assessment of productivity amongst small-holder pig farmers, Mpumalanga, South Africa : original research. Onderstepoort

Journal of Veterinary Research 83, 1–11. https://doi.org/10.4102/ojvr.v83i1.1011

Munzhelele, P., Sibeko, N.P.S., Oguttu, J.W., Mbajiorgu, C.A., Fasina, F.O., 2024. Parasites burden in peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga Province, South Africa. Journal of the South African Veterinary Association 95, 55–66.

Murto, M., Björnsson, L., Mattiasson, B., 2004. Impact of food industrial waste on anaerobic co-digestion of sewage sludge and pig manure. Journal of Environmental Management 70, 101–107. https://doi.org/10.1016/j.jenvman.2003.11.001

Muthui, N.J., Matofari, J.W., Kingori, A.M., Hülsebusch, C.G., 2019. Estimation of daily nutrient allowances for pigs fed with alternative feed resources in smallholder enterprises in Kenya. Tropical Animal Health and Production 51, 799–808. https://doi.org/10.1007/s11250-018-1757-6

Mutua, F.K., Dewey, C., Arimi, S., Ogara, W., Levy, M., Schelling, E., 2012. A description of local pig feeding systems in village smallholder farms of Western Kenya. Tropical Animal Health and Production 44, 1157–1162. https://doi.org/10.1007/s11250-011-0052-6

Myer, R.O., Brendemuhl, J.H., Johnson, D.D., 1999. Evaluation of dehydrated restaurant food waste products as feedstuffs for finishing pigs. Journal of Animal Science 77, 685–692. https://doi.org/10.2527/1999.773685x

National Research Council (U.S.) (Ed.), 1998. Nutrient requirements of swine, 10th rev. ed. ed, Nutrient requirements of domestic animals. National Academy Press, Washington, D.C.

Nayak, D.S., 2013. *Feeding of pigs* [powerpoint presentation]. 2013, Department of Animal Nutrition Co. V. Sc. & AH Jabalpur (M.P.), Available at: https://www.ndvsu.org/images/StudyMaterials/Nutrition/Feeding-of-Pigs.pdf. (Accessed: 09 March 2024).

Ncobela, C.N., Kanengoni, A.T., Hlatini, V.A., Thomas, R.S., Chimonyo, M., 2017. A review of the utility of potato by-products as a feed resource for smallholder pig production. Animal Feed Science and Technology 227, 107–117. https://doi.org/10.1016/j.anifeedsci.2017.02.008

NRC, 2012, N.R., 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. National Academies Press.

Onsongo, V.O., Osuga, I.M., Gachuiri, C.K., Wachira, A.M., Miano, D.M., Tanga, C.M., Ekesi, S., Nakimbugwe, D., Fiaboe, K.K.M., 2018. Insects for income generation through animal feed: Effect of dietary replacement of soybean and fish meal with Black Soldier Fly meal on broiler growth and economic performance. Journal of Economic Entomology 111, 1966–1973. https://doi.org/10.1093/jee/toy118

Pahm, A.A., Pedersen, C., Stein, H.H., 2009. Standardized ileal digestibility of reactive lysine in distillers dried grains with solubles fed to growing pigs. J Agriculture and Food Chemistry 57, 535–539. https://doi.org/10.1021/jf802047d

Partanen, K.H., Mroz, Z., 1999. Organic acids for performance enhancement in pig diets. Nutrition Research Review 12, 117–145. https://doi.org/10.1079/095442299108728884

Petrus, N., Mpofu, I., Schneider, M.B., Nepembe, M., 2011. The constraints and potentials of pig production among communal farmers in Etayi Constituency of Namibia. Livestock Research for Rural Development 23.

Poluektov, N.S., 1961. Techniques in Flame Photometric Analysis. Springer US.

Presto Åkerfeldt, M., Lindberg, J.E., Göransson, L., Andersson, K., 2019. Effects of reducing dietary content of crude protein and indispensable amino acids on performance and carcass traits of single-phase- and 2-phase-fed growing-finishing pigs. Livestock Science 224, 96–101. https://doi.org/10.1016/j.livsci.2019.04.014

Price, W.J., 1973. W.J. Price, Analytical Atomic Absorption Spectrometry. Heyden and Son Ltd., London, 1972, xii+239 pp., price £5.80. Analytica Chimica Acta 65, 488–489. https://doi.org/10.1016/S0003-2670(01)82524-1

Proximate Analysis, 2024. Proximate analysis feedstuff. Available at: https://unaab.edu.ng/wp-content/uploads/2009/12/459_ANN509%20Lecture%20Note%20_A_.pdf. (Accessed: 23 March 2024).

Rodrigues, L.A., Koo, B., Nyachoti, M., Columbus, D.A., 2022. Formulating diets for improved health status of pigs: Current knowledge and perspectives. Animals (Basel) 12, 2877. https://doi.org/10.3390/ani12202877

Skoog, D.A., West, D.M., Holler, F.J., Crouch, S.R., 2013. Fundamentals of Analytical Chemistry. Cengage Learning.

Statistics South Africa., 2023. Statistics South Africa. Mbalo brief, census 2022 results. Available at: https://www.statssa.gov.za/wp-content/uploads/2023/11/Mbalo-brief-November.pdf. (Accessed: 18 March 2024).

Suttle, N.F., 2010. Mineral nutrition of livestock, 4th ed. ed. CABI, Wallingford, Oxfordshire, UK ; Cambridge, MA.

Tekle, T., Genzebu, A.T., Kifleyohannes, T., 2013. Smallholder pig production and its constraints in Mekelle and southern zone of Tigray region, north Ethiopia. Livestock Research for Rural Development 25.

Villas-Bôas, S.G., Esposito, E., Mitchell, D.A., 2002. Microbial conversion of lignocellulosic residues for production of animal feeds. Animal Feed Science and Technology 98, 1–12. https://doi.org/10.1016/S0377-8401(02)00017-2

Wadhwa, M., Bakshi, M.P.S., 2013. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products. RAP publication 4, 67.

Westendorf, M.L., Schuler, T., Zirkle, E.W., Hays, V.W., Wilson, L.L., 1999. Nutritional quality of recycled food plate waste in diets fed to swine. The Professional Animal Scientist 15, 106–111. https://doi.org/10.15232/S1080-7446(15)31737-X

Widayati, T., Rahayu, B., Rahardjo, D., Lekitoo, M., 2019. Feeding effect of different levels of agricultural and food waste on growth performance and economics in pig production. Journal of Agricultural Science and Technology A 9. https://doi.org/10.17265/2161-6256/2019.04.004

World Economic Forum, 2024. Extreme weather is driving food prices higher. These 5 crops are facing the biggest impacts [www Document]. World Economic Forum. Available at: https://www.weforum.org/agenda/2024/02/climate-change-food-prices-drought/. (Accessed: 14 March 2024).

Yin, L., Li, Jun, Wang, M., Wang, Q., Li, Jianzhong, Ding, N., Yang, H., Yin, Y., 2021. Dietary high protein-induced diarrhea and intestinal inflammation by activation of NF-κB signaling in piglets. Animal Nutrition 7, 1070–1077. https://doi.org/10.1016/j.aninu.2021.05.002

CHAPTER SIX

OVERALL CONCLUSION AND RECOMMENDATIONS

6. Introduction

This chapter provides an overview of the research findings and examines the implications of the study. This was with a view to drawing conclusions and offering evidence-based recommendations for implementation and future research. It also provides pig producers, agricultural advisors, animal health practitioners and researchers with important information to guide efficient agricultural practices, as well as provides empiricism to decision-makers and policymakers to develop useful frameworks that will assist in translating the research into policy.

6.1. Key findings from this study

This study provides evidence-based empirical findings that should significantly influence free-roaming pig production in peri-urban areas as a means to alleviate poverty, create employment opportunities, assist in improving the health of FRPs by understanding the various nutritional aspects of swill feeding for pigs along with the need to administer medication to the pigs, along with the associated potential and challenges associated with pig farming.

The following section addresses study objective 1, that is: **To conduct an exploratory analysis of the free-roaming production systems and identify production constraints in peri-urban areas of Mpumalanga province.**

Free-roaming pig farming in the study area is male-dominated and a significant proportion of these pig producers have a limited level of education, lack any formal land ownership documents and are not familiar with pig identification marks. These findings present an opportunity to engage at multiple levels with critical stakeholders to standardize farming practices, implement hygiene protocols, create an enabling environment for economic improvement and service delivery. The public health in peri-urban areas is compromised by the occurrence of home slaughtering of pigs that fails to comply with appropriate slaughtering protocols for public consumption as well as the limited awareness of transboundary animal diseases, including ASF, foot-

and-mouth disease and tuberculosis. Crossing of roadways by FRPs increased the risk of their theft and being killed by motor vehicle accident.

According to 66.1% of the study participants, animal theft was a significant issue associated with peri-urban free-roaming pig farming. Empirical statistics and researchers' experiences indicate a correlation between stock theft and non-compliance with the Department of Agriculture, Land Reform, and Rural Development's (DALRRD) regulations for legal registration and the use of permitted animal identification marks. Animals equipped with authorized identities are more challenging to steal and deliver for slaughter at authorized establishments. According to the findings, 72.6% of the study participants indicated they had not registered pigs for animal identification marks or complied with the laws regarding this matter. Farmers must apply to the DALRRD to register an identification mark under the Animal Identification Act (No. 6 of 2002). Pigs need tattoos identifying them as animals owned by registered farmers. The Act may also require a review to identify compliance barriers for small-scale pig producers.

Most of the peri-urban free-roaming pig producers (55.6%) depended on their neighbours' boars to assist in impregnating their sows, a practice which can spread reproduction-related diseases such as brucellosis, porcine reproductive and respiratory syndrome, and classical swine fever. If this practice is not monitored, inbreeding can occur that results in a general devaluation in the farmer’s pigs as a result of low weaning weight, low litter size, slow-developing piglets, runting, congenital abnormalities, and poor reproductive performance. The practice of allowing pigs to roam freely and breed without restrictions in peri-urban pig farming can lead to the breeding of large exotic boar breeds with smaller indigenous sow breeds. This can result in dystocia and high mortality rates. This will have a significant impact on purebred species conservation in the future, resulting in the eventual loss of most indigenous breeds.

The following section addresses study objective 2, that is: **To establish the prevalence of ecto- and endoparasites in free-roaming pigs (FRPs) in peri-urban areas of Mpumalanga province.**

In terms of parasite infestation of the pigs, most of the parasites identified in this study were *Sarcoptes scabiei* and *Coccidia* spp., with a prevalence of 62.9% and

53.7%, respectively. Reduced prevalence of infestation was noted with *Ascaris suum* (37.8%), *H. suis* (31.1%), *Trichuris suis* (13.4%) and *Strongylid nematodes* (10.2%). This investigation infrequently detected *Siphonaptera* spp*., Moniezia expansa*, and *Fasciola hepatica*. In stratifying these data in relation to pig breed, exotic pig breeds were more susceptible to parasites such as *Moniezia expansa* (100%), *Siphonaptera spp.* (100%). *Sarcoptes scabiei* (79.8%), *Coccidia* spp*.* (75.7%), *Ascaris suum* (73.8%), *Trichuris suis* (68.4%), and *H. suis* (68.2%), and *Strongylid* nematodes (79.3%). Infestation of pigs with parasites have significant economic implications for pig farming as it contributes to an increase in the following: stunted growth, pig mortality, condemnation of certain organs during slaughter, and damage to the skin of the pigs. Regarding gender, female pigs had a greater parasite burden (n=167) compared to male pigs (n=116).

Peri-urban farmers engaging in free-roaming pig production should prioritize indigenous pig breeds, followed by crosses of exotic and indigenous breeds, as these were found to exhibit the lowest parasite burden compared to exotic breeds. Farmers should regularly administer antiparasitic medication to pigs, particularly pregnant sows, to prevent the transmission of parasites to piglets post-farrowing, as older pigs were found to exhibit a high incidence of various parasites, including pigs aged four months and younger.

To facilitate pig handling, farmers can administer antiparasitic medication in powdered form mixed with feed. In addition, the FRP farmers would benefit from establishing a cooperative or study group to concurrently administer deworming and vaccinations, so mitigating the risk of reinfection post-treatment. Furthermore, establishing a cooperative would enable peri-urban pig farmers to purchase in bulk at reduced prices as well as receive training in pig management, biosecurity, and other critical matters.

The following section addresses study objective 3, that is: **To investigate the composition of the different swills and how swill can be reconstituted to meet the nutrient requirements for FRPs in peri-urban areas of GSDM in Mpumalanga province.**

A primary finding of this study revealed that swill feeding was the most prevalent method for feeding free-roaming pigs by farmers in the peri-urban areas of the GSDM

in Mpumalanga province. All the swill in the present study displayed an elevated level of moisture content. The crude protein (CP) content levels, specifically those in swill collected from warehouses (387.07 g/kg DM, 38.707%) and restaurants (236.12 g/kg DM, 23.61%), exceeded the recommended CP content for all feeding pig age groups. According to the standard feed requirement set by DAFF, the acceptable CP content should range from 12% to 19%. In addition, the Na concentration level in the SS (0.85%) was exceeding the permitted threshold of 0.5% for pig feed. Excessive sodium consumption in the diet is hazardous, as it can lead to significant health problems, toxicity, and the development of soft pork.

Overall, feeding pigs with a high concentration of CP allows them to metabolize extra protein and use it as an energy source. Four types of swill were collected and analysed for nutritional content in the present study. This may present researchers with an opportunity to collect swill from various sites in the GSDM before mixing swill types to improve the ratio of the various components in the original swill types. Carefully combining swill types in particular ratios may lead to swill types containing varying proportions of nutritional components to improve the nutritional value of a swill mix that is optimized for pigs of different age and condition. Such a swill combination exercise may, at the least, increase and improve the nutrient value of poorer quality swill types while also diluting potentially harmful levels of swill components.

Peri-urban free-roaming is facing significant challenges due to the failure of pig producers (92.7%) to properly treat the swill before feeding it to the pigs. This practice is in violation of the Animal Diseases Act, 1984 (Act No. 35 of 1984). This can lead to the emergence of disease outbreaks in peri-urban pig farming environments. Because farmers continue to engage in swill feeding, a practice that will not change soon, it will be necessary for the authorities and the stakeholders to define a progressive scale-up approach, which the farmers can engage in until they reach zero-swill or safe swill feeding. An associated monitoring pathway will also be useful.

6.2. Implications of the study findings

The free-roaming of pigs increases their vulnerability to multiple threats, such as infections, parasites, theft, predation, accidents, interactions with visitors, and

contact with diseased animals, which can result in economic losses. The free-roaming pigs have the ability to access and pollute dams, sewage systems, tainted carcasses, contaminated manure, and infected urine, which might potentially expose humans to further zoonotic hazards. Additionally, the presence of free-roaming dogs or other wild animals can lead to predation, which exposes the pigs to rabies and other related diseases. These factors indicate that animal, social, environmental and health rights violations are a norm regarding FRP farming in the GSDM.

The Animal Protection Act 71 of 1962 grants animals the five freedoms and prohibits any form of animal cruelty toward them. However, the Gert Sibande District's free-roaming system overlooks this thereby infringing upon all five animal rights. This research has uncovered several issues related to the welfare of pigs. Firstly, there is a shortage of feeds (11.3%), which violates the principle of freedom from hunger and thirst. Additionally, the pens are often muddy (8.9%), and the pig houses are either absent or poorly constructed (19.4% or 1.6%), which goes against the principle of freedom from discomfort. Furthermore, the data showed that 29.8% of the pigs experienced predation, with causes including attacks by dogs, wild animals, being bitten by people, and poisoning. These incidents violate the principles of freedom from pain, injury, or disease, as well as freedom from fear and distress. Lastly, theft is a common challenge in peri-urban free-roaming, which hinders the pigs' ability to express normal behaviour. In addition to infringing upon the five animal rights, free-roaming pig farming currently occurs in peri-urban areas near residential areas, a practice that violates environmental impact assessment (EIA) rules. Thus, FRP farming occurs without the necessary approval from the EIA and without complying with various acts, such as the Air Quality Act of 2004 (Act No. 39 of 2004), the Waste Act of 2008 (Act No. 59 of 2008), and the National Environmental Management Act of 1998 (Act No. 107 of 1998).

In addition, free roaming pigs carry a variety of ecto- and endoparasites so that in the peri-urban areas of Gert Sibande District Municipality, this study identified nine different types of parasites. Parasitic infections challenge pig performance by reducing the rate of pig growth, decreasing reproductive efficiency in sows and boars, and lowering feed conversion efficiencies. Relatively few FRP farmers indicated that they actively and regularly responded to improved feeding and veterinary needs of their pigs and, as a result of the poorer performance shown by

their pigs, the pig farming business in the area experiences a decline in income returns.

The practice of feeding untreated swill to the pigs may contribute to the spread of African Swine Fever (ASF). In the recent past, the peri-urban area of Gert Sibande District Municipality has had a significant outbreak of ASF and this has contributed to a continuous decline in the pig population in Mpumalanga province. To avoid challenges in peri-urban pig farming, epidemic diseases such as ASF, which will persist in pigs showing signs of declining genetics and health in general, there is a need to improve the general care provided to FRP including veterinary care, swill quality and pig housing.

Overall, these findings have significant ethical, veterinary and public health importance, as they reflect negatively on the care meted out by farmers to assets such as their pigs, resulting in adverse effects on pig performance and productivity. This, in turn, has a negative knock-on effect on food security, health and livelihoods among the poor living in the peri-urban areas of Mpumalanga.

6.3. Recommendations

To effectively address the issues and opportunities of peri-urban free-roaming pig farming in Mpumalanga, it is essential to implement a One Health approach that promotes the welfare of humans, animals, and the environment through collaborative problem-solving at local, national, and global levels (Mackenzie *et al*., 2019). Furthermore, this should address concerns such as biosecurity, swill treatment, parasite management, and pig movement regulations.

In the current circumstances and due to multiple challenges, free-roaming pig farming is inappropriate in peri-urban areas. Health concerns are one of these as the practice of FRP farming appears to have facilitated a recent disease outbreak while the present study identified nine distinct parasites infesting pigs in the GSDM. The ability of pigs to move along roadways, scavenge in garbage sites, have direct and indirect contact with humans and other animals, and consume water from linking sewage systems compromises the public health of the community and increases the risk of disease infection and spread. Moreover, the practice of slaughtering pigs without prior

inspection from an animal health practitioner significantly endangers public health within the community. It is widely recognized that pigs are natural diggers; in this study, 79% of pig housing featured soil floors, rendering cleaning unfeasible and perhaps promoting a habitat for parasites. In addition, all peri-urban free-roaming pig farmers provided pigs with untreated swill, which is against the mandate of the Animal Disease Act. The application of biosecurity is entirely unfeasible in free-roaming conditions within a peri-urban environment. Peri-urban free-roaming pig farming is exceedingly hazardous since it may lead to diseases such as ASF. This could lead to financial losses, harm to public health, and a ban on the export of pork. Given all the challenges reported in this study, peri-urban pig farming should be transitioned to a restricted pig farming system, or if that is not feasible or enforceable, it should be prohibited.

In addressing this, the Department of Agriculture, Rural Development, Land, and Environmental Affairs (DARDLEA) should focus on addressing inadequate disease control and pig management in peri-urban areas. To improve pig management, the DARDLEA should also organize information days, raise awareness, and develop guidelines about peri-urban pig management.

Pig producers, swill suppliers, the government, local authorities, market facilities, and the local communities need to collaborate and form partnerships. Such a collaboration will promote safe swill use as pig feed and pig welfare and address some of the negative aspects of peri-urban FRP farming. In practice, a transition from free-roaming practices to a more intensive style of farming will need the establishment of a cooperative among pig farmers in peri-urban areas. Subsequently, the engagement of the cooperative with the municipality should take place with a view to designating an area that is not zoned for human habitation nor intended for development for leasing purposes. This will assist pig farmers in fencing the designated area and provide shelter at night and during harsh weather for their pigs. The municipal authorities should mandate peri-urban free-roaming pig producers to register for animal identification and to implement identification on the pigs in compliance with the Animal Identification Act (No. 6 of 2002). To prevent inbreeding, pig farmers should castrate all male pigs and retain only boars designated for breeding, which they should exchange annually. Pig farmers providing swill to pigs must process the swill in compliance with the Animal Diseases Act (Act No. 35 of 1984). Furthermore, the pigs

must be regularly treated to mitigate parasite load. These measures will enhance biosecurity, pig health, and productivity. In accordance with EU and national legislation, all South African pig farms or operations must be registered in national pig databases, regardless of their size, category, or commercial activity (AHAW, 2021).

In regard to improving pig feed, peri-urban pig producers need to receive training and an awareness campaign on swill management, using swill as pig feed, and biosecurity to prevent pandemic diseases caused by feeding swill. This includes proper swill management, knowing the nutritional makeup of different swill varieties, removing undesired elements, and protecting pigs that eat swill. The study revealed that all of the swill had a low dry matter (DM) content and a greater moisture content, which means that the pig needs to consume a bigger volume of feeds in order to reach the desired DM% level. Promoting the practice of drying out or dehydrating the swill can resolve this issue. Findings from this study demonstrated that the nutritional composition of the household swill was of less favourable quality compared to other types of swill. However, to ensure a suitable diet for piglets and weaners, the study recommends the mixing of swill feed with different nutritional content by combining household swill and wholesaler swill. In addition, it is advisable to promote the use of a blend of swill from both schools and restaurants to create a diet that could be suitable for the grower pigs. The study found the school swill to be suitable as feed for both finishing and breeding purposes.

6.4. Suggestions for future research

Future research should:

- Focus on investigating the growth performance of pigs fed different types of swill.
- Examine the pork quality in relation to the type and quality of swill fed to pigs in peri-urban free-roaming environments.
- Assess the presence of parasites in the organs of peri-urban free-roaming pigs.
- Assess the potential risk of free-roaming pigs as a possible cause of diseases such as ASF in, and from, peri-urban areas.
- Treat swill with techniques such as dehydration to reduce the risk of disease and preserve nutrient content.

- Mix swill types to improve their overall quality and nutrient content.

6.5. Final remarks

- Better-managed peri-urban free-roaming pig farming offers significant economic potential to alleviate poverty, improve food security, and increase household income. Nevertheless, local government acts and policies regarding peri-urban animal husbandry must incorporate this sector and offer precise instructions to enhance biosecurity as well as human and animal health.
- Transitioning from a free-roam to a restricted system can greatly enhance pig farming in peri-urban areas, as it will reduce theft, death caused by predation, accidents caused by road crossing, consumption of feeds from garbage and unknown places, and water from sewerages. Construction of pig housing from readily available local materials, including a concrete floor to facilitate biosecurity measures and effective deworming of pigs. Transitioning to a more enclosed environment for the pigs will assist peri-urban pig producers in improving the health of their pigs and managing the introduction and use of exotic pig breeds characterized by rapid growth and large litter sizes.
- Increased access to land by municipal authorities that is designated for agriculture will promote the expansion of activities and adherence to official regulations in the peri-urban farming.
- The farmers' low adherence to biosecurity measures increases the potential for disease outbreaks that have economic and public health implications. This, combined with the observed illegal slaughter of pigs, pose a significant public health concern. This illegal technique highlights the gap between the regulations governing free-roaming pig farming and the industry's actual functioning.
- Increased enforcement of laws on free-roaming pig farmers might be challenging but the municipality must establish impounding areas for non-compliance of the law as a means of ensuring adherence to the laws by farmers. The DARDLEA and Gert Sibande District Municipality need to collaborate in implementing crucial policies for peri-urban free-roaming pig farming.

- The DALRRD possesses guidelines on urban and peri-urban animal agriculture; however, the guidelines are outdated. Consequently, this requires a modification.
- Nearly 90% of FRPs in the GSDM tested positive for one or more parasites, identifying a total of nine different parasites.
- In light of the increasing prevalence of various diseases in the Republic of South Africa, this study proposes the need for a revision of agricultural legislation pertaining to peri-urban farming. This is necessary to effectively manage and prevent the spread of parasites in food production systems in peri-urban areas. Policymakers, animal researchers, and veterinary services should prioritise the development of policies and materials for risk communication and community engagement (RCCE). These efforts should specifically target pig farmers in peri-urban areas, such as the Gert Sibande District Municipality in Mpumalanga Province.
- The cost of conventional diets for pigs is high, particularly for young pigs. Swill may be utilized as feed for pigs but this study indicates that the nutritional content of each swill type varied, being either above or below the average dietary requirements for pigs of various ages. To effectively balance and meet the nutritional needs of pigs relying on swill as the primary nutrient source, it is essential to supplement the swill with alternative feed types or to combine different swill types. For instance, a suitable diet for piglets and weaners may be developed by integrating Wholesaler Swill, which is nutritionally rich, with Household Swill, which is of low nutritional quality. Conversely, the integration of SS and RS may yield an appropriate diet for growing pigs. Moreover, the swill must be dehydrated prior to being administered to pigs.

References

EFSA Panel on Animal Health and Welfare (AHAW), Nielsen, S.S., Alvarez, J., Bicout, D.J., Calistri, P., Canali, E., Drewe, J.A., Garin-Bastuji, B., Gonzales Rojas, J.L., Herskin, M. and Miranda Chueca, M.Á., 2021. African swine fever and outdoor farming of pigs. EFSA Journal, 19(6), p.e06639.

APPENDICES

Appendix 1: Consent form

PARTICIPANT INFORMATION SHEET
Ethics clearance reference number: 2019/CAES_HREC/108
Research permission reference number: REC-170616-051

_____/_____ 20____

TITLE: FREE-ROAMING PIG PRODUCTION IN THE PERI-URBAN AREAS OF GERT SIBANDE DISTRICT IN MPUMALANGA PROVINCE, SOUTH AFRICA: HUSBANDRY PRACTICES, NUTRITION, AND PARASITE BURDEN.

Dear Prospective Participant
I am Priscilla Makungo, and I am now conducting research under the guidance of Prof. James Oguttu, a distinguished professor in the Department of Agriculture and Animal Health. I will be awarded a PhD (Agriculture) degree from the University of South Africa as a result of my study. You are being invited to take part in a study entitled "Pig management in the peri-urban areas of Gert Sibande District in Mpumalanga Province, South Africa, under the free roaming system".

WHAT IS THE PURPOSE OF THE STUDY?
The aim of this study is to investigate the management and health status of pig reared under the free roaming system in peri-urban areas of Gert Sibande District in Mpumalanga province, South Africa.

WHY AM I BEING INVITED TO PARTICIPATE?
As a free-roaming pig farmer in the peri-urban areas of Gert Sibande District, we kindly request your participation in the present research regarding pigs in the peri-urban, ecto- and endo-parasites, pig nutrition and management used for the pigs.
The Mpumalanga Department of Agriculture, Rural Development, Land Administration, and Environmental Affairs granted permission to conduct the study. The total number of participants in this study is estimated to be approximately 380.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?
The study will administer questionnaires face-to-face. The fresh faeces (200 ml) from the rectum and scraping of the skin for external parasites will be collected from the pigs. The swill (500 g) will be collected from the storage bin and feeding troughs. The GPS coordinates collection points, and the camera captures pig photos. The expected duration of participation and the time needed to collect data are approximately 30 minutes per participant.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participation in this research is entirely voluntary. It is the participant's choice whether to participate or not. The participant may change their mind later and stop participating, even if they agreed earlier.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

Pig production is an important economic activity for South Africa's population. The results of this study will improve the understanding of peri-urban pig production, train emerging free-roaming pig farmers, and improve disease management. It will help reduce the incidence of contagious and zoonotic diseases in peri-urban areas. We will use it to develop a guideline for free-roaming pig farmers and publish it in peer-reviewed journals. It will improve pigs' understanding of swill as a source of nutrition. The prevalence of identified parasites will be outlined, with the possibility of designing an annual plan on parasite prevention and management. Addressing socio-economic limitations will motivate FRP farmers to improve their farming systems. It will assist policymakers in developing appropriate peri-urban farming policies, particularly for pigs.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

Participating in this study has no foreseeable risk of harm or side effects for you. The only inconvenience to you will be the valuable time you will sacrifice answering the questions in the questionnaire.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

Only members of the research team will have access to all participant answers, which will be strictly confidential. No data published in dissertations or journals will contain any information about names, addresses, or pictures. Your anonymity is therefore ensured.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Researchers in this study will collect questionnaires using ArcGIS Survey123 software, which requires a protective password. Only the researcher will have access to the questionnaires. The researcher will convert the raw data from the ArcGIS Survey123 software into a Microsoft Excel Spread Sheet, store it on their computer with a protective password, and store an external drive as a backup. The researcher will retain the data for three years after the study concludes.

WILL THIS STUDY PROVIDE ME WITH ANY COMPENSATION OR INCENTIVES?

Participation in this study comes with no payment.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Department of Agriculture, Forestry, and Fisheries, as well as the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, UNISA, and the Department of Agriculture, Land Reform, and Rural Development for Section 20. If you wish, you can obtain a copy of the approval letter from the researcher.

HOW WILL I RECEIVE INFORMATION ABOUT THE RESEARCH'S FINDINGS AND RESULTS?

To obtain the final research findings, please contact Ms. Priscilla Makungo at +27 66 485 5294, +27 17 819 2781, or 41831438@mylife.unisa.ac.za. As of December 2024, the findings will be available.

If you have any concerns about the conduct of the research, feel free to email Prof. James Oguttu at joguttu@unisa.ac.za. If you have any ethical concerns, please contact Prof. EL Kempen, the research ethics chairperson of the CAES General Ethics Review Committee, at 011-471-2241 or kempeel@unisa.ac.za.

Thank you for taking the time to read this information sheet and participate in this study.

Warm regards
Ms. Priscilla Makungo
UNISA and DARDLEA
Animal Research (Mono-gastrics)
Nooitgedacht Research Farm
Bethal Road, Ermelo, 2350
E-mail: 41831438@mylife.unisa.ac.za

CONSENT TO PARTICIPATE IN THIS STUDY

I, _____ (participant name), confirm that the person asking for my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.
I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.
I agree to the recording of the questionnaire.

I have received a signed copy of the informed consent agreement.

Participant Name and Surname : _____ (Please print)

Participant signature :_____ Date : _____

Researcher name and Surname: _____ (Please print)

Researcher signature: _____ Date: _____

Appendix 2: Questionnaire

ANNEXURE A

Free-roaming pig production in the peri-urban areas of Gert Sibande District in Mpumalanga province, South Africa: husbandry practices, nutrition, and parasite burden.

Dear Sir / Madam

The survey is conducted in Gert Sibande District Municipality, in the peri-urban areas of all seven local municipalities, to investigate the production system and constraints in the peri-urban area and to explain the socio-economic benefits and economic constraints of practicing free roaming pig farming.

Please do not enter your name on the questionnaire. It's still anonymous. We will only report the information you provide in summary format, keeping it confidential. We will keep your participation in this research confidential, and if the research results in a publication or presentation, we will not share any personally identifiable information. Your decision to be part of this research is voluntary, and you may stop at any time you wish. You do not have to answer any questions if you do not want to.

Should you have any queries or comments regarding this survey, you are welcome to contact me telephonically at 017 819 2781 or e-mail us at 41831438@mylife.unisa.ac.za.

Yours sincerely
Priscilla Makungo
PhD. Candidate at University of South Africa

Questionnaire number _____ **Date:** _____

Municipality: Msukaligwa ☐ **Govan Mbeki** ☐ **Lekwa** ☐

Mkhondo ☐ **Chief Albert** ☐ **Dipaleseng** ☐ **Pixley ka seme** ☐

(Pig dwelling) GPS coordinates: ºS_____ **ºE** _____

Kindly respond to the subsequent inquiries by marking (X) in the appropriate box or by inscribing your answer in the designated space provided.

Example on how to complete this questionnaire

Your gender (if you are a female)

1.Male	2. Female

A. FARMER'S PROFILE

1. What is your gender?

1. Male	2. Female

2. What is your age?

1. 18 – 35 years
2. 36 - 59
3. 60 and above

3. What is your monthly income?

1. None
2. Below R1000
3. Between R1 001 – R2 000
4. Between R2 001 – R5 000
5. Between R5 001 – R10 000
6. Between R10 001 – R20 000
7. More than R20 001

4. Highest level of education?

1. None
2. Stopped in primary
3. completed primary but did not complete matric
4. Completed matric
5. Diploma and above

5. Size of the household

1. Live alone
2. Two
3. 3 – 5 people
4. 6 – 10 people
5. 11 and above

B. FARMING PROFILE

6. Type of faming

1. Livestock	2. Crop	3. Mixed

7. What type of livestock do you keep?

1. Pigs	2. Cattle	3. Goats	4. Sheep	5. Poultry	6. Horse	7. Other (Specify)

8. Type of pig breed you rearing?

1. Large white (LW)	2. Landrace (L)	3. cross of LW x L	4.Indigenous breed	5. Warthogs	6.Other (Specify)

9. Total number of pigs on the farm

1.Piglets:	2.Weaners:	3.Grower:	4.Sows:	5. Boar:

10. Land ownership?

1. Leasing from municipality	2. Farming without permission	3. Owning the land	4. Other (Specify)

C. MANAGEMENT SYSTEMS

11. Do you house the pigs overnight?

1. Yes	2. No

12. Type of house for pigs?

1. Brick house with roof	2. Woods house with roof	3. Corrugated house with roof	4. Roofed with no surrounding	5. No housing	6. Other (Specify)

13. What type of floor is in the house?

1. Concrete	2. Soil	3. Other (Specify):

14. Do you have handling facility?

1. Yes	2. No

15.	Yes	No	I don't know	Other (Specify):
15.1 Are you registered with DAFF for identification certificate?				
15.2 If yes, do you practice tattooing?				
15.3 Do you slaughter at home?				
15.4 If yes, do you request the state vet to perform pig inspection before slaughter?				
15.5 Do you know where your pigs find food?				

15.6 Do the pigs walk across the roads?				
15.7 If yes, have they ever experience any mortality due to accident?				
15.8 Mortality due to accident average number per year?				
15.9 Do they scavenge around the dwelling (homes) areas only?				
15.10 Do you castrate the male pigs				
15.11 Do you experience theft of pigs?				
15.12 Theft average number per year?				
15.13 Do you experience mortality of pigs due to predation?				
15.13 Mortality due to predation average number per year?				

16. What causes predation?

1. Dogs	2. Wild animals	3. Other (Specify):

17. What age dofemale pigs usually become pregnant (1st gestation)?

1. 3 – 5 months	2. 6 – 8 months	3. 9 – 10 months	4. < 12months	5. Other (Specify)

18. How do you identify your pigs?

1. Tattooing	2. Ear notch	3. Ear tag	4. Other (Specify):

19. How many times do you monitor your pigs per month?

1. Daily	2. More than once a week	3. Weekly	4. Monthly	5. Never	5. Other (Specify):

20. When do you allow the pigs to scavenge?

1. Summer	2. Winter	3. Always	4. Other (Specify):

D. PIG HEALTH

21. Do you vaccinate your pigs?

1. Yes	2. No

22. If yes, specify the vaccine?

_____

23. Do you treat the pigs against ecto and endoparasites?

1. Yes	2. No

24. If yes, specify the medicine used?

_____

25. Do you use the disinfectant in pig farming?

1. Yes	2. No

26. If yes, please specify the disinfectant?

_____

E. ECONOMIC BENEFITS

27. How did you acquire the pig stock?

1. Given by someone	2. Bought using savings	3. Borrowed money to buy stock	4. Other (Specify)

28. How long have you been farming with pigs?

1. 1 year	2. 2 – 5 years	3. 6 – 10 years	4. 11 years and above

29. Reasons for keeping pigs?

1.Sale	2.Household consumption	3.Tradition	4.Hobby	5. Other (Specify):

30. Pig production

30.1 How many piglets does one sow farrow?	None	1 - 5	6 - 10	11 – 15	More than 16
30.2 How many piglets do you wean?	None	1 - 5	6 - 10	11 – 15	More than 16
30.3 Age at weaning?	1 – 35 days	36 – 60 days	61 – 90 days	No weaning	
30.4 Age at marketing	After weaning	2 months - 4months	5months-10months	11months -18months	>19months
30.5 Where do you sell your pigs	Sell live pigs from home	Slaughter at home and sell	Sell live pigs local	Auction	Abattoir
30.6 Price of slaughtering at home	Very low	Low	Moderate	High	Very high
30.7 Price of selling live pigs locally	Very low	Low	Moderate	High	Very high
30.8 Price of selling at auction	Very low	Low	Moderate	High	Very high
30.9 Price of selling at abattoir	Very low	Low	Moderate	High	Very high

30.10 What is your annual gross income from the sale?	Zero	R1 – R5000	R5100– R20000	R21100-R50000	>R51100
30.11 Total price of the feeds fed per year	Zero	R1 – R5000	R5100 – R20000	R21100-R50000	>R51100
30.12 Cost of veterinary purchases per annum	Zero	R1 – R500	R510 – R1000	R1100-R1500	>R1560
30.13 Cost of labourers per annum	Zero	R1 – R5000	R5100-R10000	R10100-R15000	>R15100

31. The selling price of the following (Home sale)

1.Piglets: R	2.Weaners: R	3.Growers: R	4.Finisher: R	5.Sow: R	6.Boar: R

A. PIG NUTRITION

32. What do you feed to your pigs?

1.Commercial feeds	**2.Mix at home**	**3.Swill**	**4.None**	**5. Other (Specify)**

33. Where do you get the swill?

1.Households	**2.Resturants/ Hotels**	**3.Schools**	**4.Hospital**	**5. Market**	**5. Other (Specify)**

34. Do you buy swill?

1. Yes	**2. No**	**3. Sometimes**	**4. Other (Specify)**

35. If yes or sometimes, How much per 25L R_____

If no, how do you pay those providing swill for you _____

36. Problems related to swill feeding _____

37. Do you treat the swill after getting it?

1.Boiling	**2. Chemical additives**	**3. Composting**	**4.Heat (ensiling)**	**5. Other (Specify)**

38. Where do you feed your pigs?

1. Feeders	**2. Concrete floor**	**3. Soil floor**	**4. bucket**	**4. Other (Specify)**

39. Swill feeds

39.1 After how long is the swill fed after collection?	Same day	A week	2 weeks	>3 weeks	Other (Specify)
39.2 How is the swill stored?	Plastic drums	Steel drums	Open room	Other (Specify)	
39.3 Do you weigh the swill before feeding?	Yes	No	Sometimes	Ad lib	Other (Specify)
39.4 How do you determine feeds per pig?	Ad lib	As supplements to other feeds	Other (Specify)		

40. Are you aware of zoonosis diseases in pigs?

1. Yes	2. No

41. If yes, please specify: _____

Thank you for taking part in answering the following survey. Kindly submit the survey as outlined on page one.

Appendix 3 Plates for Chapter 3

Appendix 3.1: Photographs taken during data collection.



Appendix 3.1a: Microscopic view of *H. suis.* Photograph taken by P.M.



Appendix 3.1b: Pig eating dead broilers. Photograph taken by P.M.



Appendix 3.1c: Pigs feeding with dogs. Photograph taken by P.M.



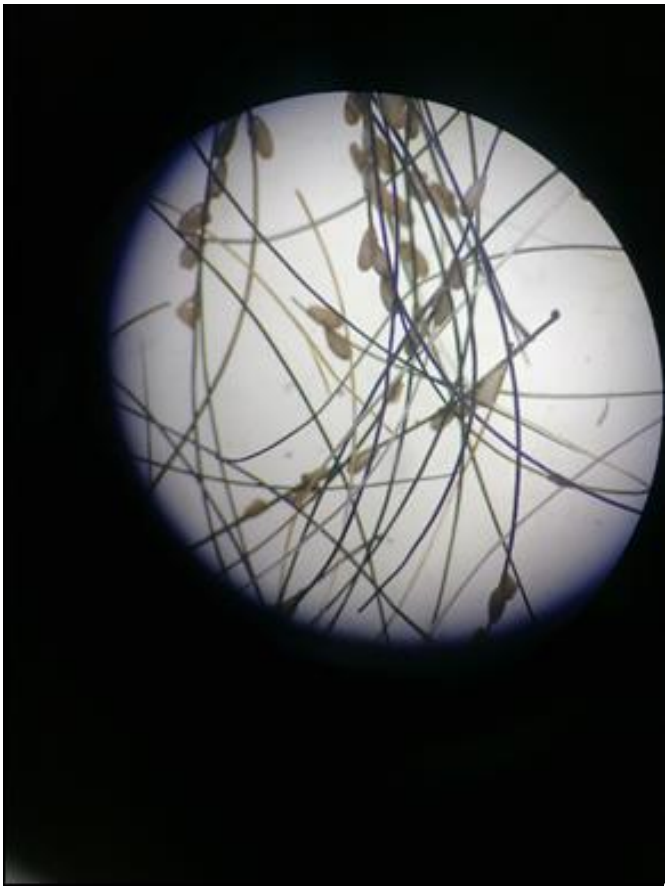
Appendix 3.1d: Boar held with pig snare during data collection. Photograph taken by P.M.



Appendix 3.1e: Example of method of feed (swill) storage in barrel. Photograph taken by P.M.



Appendix 3.1f: Example of *Ascaris suum* collected during study. Photograph taken by P.M.



Appendix 3.1g: Microscopic view of *H. suis* eggs attached to pig hair. Photograph taken by P.M.

Appendix 3.2: Score sheet for weighing pigs, faecal and skin scrape samples

Questionnaire number: _____

Municipality: _____

Picture for body condition score



1. Emaciated	2. Thin	3. Ideal	4. Fat	5. Overfat

Picture courtesy: American Mini Pig Association (www.americanminipigassociation.com).

Body condition scoring

ID no	AGE	SEX	BREED	BCS	WEIGHT	OBSERVATIONS

Appendix 4: UNISA CAES Animal Research ethics approval

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE
UNISA-CAES ANIMAL RESEARCH ETHICS COMMITTEE

Date: 09/09/2019

NHREC Registration # : REC-170616-051
REC Reference # : 2019/CAES_HREC/108
Name : Ms P Munzhelele
Student #: 41831438

Dear Ms Munzhelele

Decision: Ethics Approval from 06/09/2019 to completion

Researcher(s): Ms P Munzhelele
priscilla.munzhelele@gmail.com

Supervisor (s): Prof JW Oguttu
joguttu@unisa.ac.za; 011-471-3353

Prof FO Fasina
daydupe2003@yahoo.co.uk; +255-22-2664557-9

Prof CA Mbajiorgu
mbajica@unisa.ac.za; 011-471-3590

Working title of research:

The untold story of the free roaming pigs in the peri-urban areas of Mpumalanga Province, South Africa

Qualification: PhD Agriculture

Thank you for the application for research ethics clearance by the Unisa-CAES Health and Animal Research Ethics Committees for the above mentioned research. Ethics approval is granted until the completion of the project, **subject to submission of yearly progress reports**. **Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

Due date for progress report: 31 August 2020

Please note the points below for further action:

1. If any case of African swine fever (ASF) is noticed, the researcher is cautioned that the involved veterinarians should be informed.

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Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
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2. The researcher is cautioned to exercise the necessary precautions to ensure her own safety during the handling of the pigs. Simultaneously, the researcher is advised not to include difficult pigs in this study as unnecessary force may be required to restrain them. Should it take too long to capture a pig and do the procedure (e.g. ten minutes or more) the pig should be released.
3. The researcher should take note that this is a hot and humid time of year in the research area. She should ensure that environmental factors do not lead to unnecessary stress for the animals. She should, for instance, do the capturing during the early morning period when the heat is not yet excessive.
4. The researcher is cautioned that she should consider the condition of targeted animals and make a decision on whether they are in sufficient health to withstand the stress of capture. She should be guided by the veterinarian in this assessment.
5. The researcher indicates that the stipulations of the Animal Protection Act will be followed – which part of the Act is applicable to this project? Researchers should not make blanket statements but show an understanding of why certain legislation is applicable.

*The **high risk application** was **reviewed** by the UNISA-CAES Health and Animal Research Ethics Committees on 05 and 06 September 2019 respectively in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal

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Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.

6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:
*The reference number **2019/CAES_HREC/108** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committees.*

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof EL Kempen
Chair of UNISA-CAES Animal REC
E-mail: kempeel@unisa.ac.za
Tel: (011) 471-2241

Prof MJ Linington
Executive Dean : CAES
E-mail: lininmj@unisa.ac.za
Tel: (011) 471-3806

Please NOTE CONDITIONS

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Appendix 5: DAFF section 20 of Animal Diseases Act

agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Directorate Animal Health, Department of Agriculture, Forestry and Fisheries
Private Bag X138, Pretoria 0001

Enquiries: Mr Herry Gololo • Tel: +27 12 319 7532 • Fax: +27 12 319 7470 • E-mail: HerryG@daff.gov.za
Reference: 12/11/1 (1237)

Ms Priscilla Munzhelele
Nooitgedacht Agriculture Development Centre
Tel: 079 246 8769/ 071 403 0421/ 066 485 5294
Fax: 079 819 1223
E-mail: priscilla.munzhelele@gmail.com

Dear Ms Munzhelele

RE: PERMISSION TO DO RESEARCH IN TERMS OF SECTION 20 OF THE ANIMAL DISEASES ACT, 1984 (ACT NO 35 OF 1984)

Your application dated 20 June 2019 requesting permission under Section 20 of the Animal Disease Act, 1984 (Act No. 35 of 1984) to perform a research project or study, refers. I am pleased to inform you that permission is hereby granted to perform the following study, with the following conditions:

Conditions:

1. This permission does not relieve the researcher of any responsibility which may be placed on him by any other act of the Republic of South Africa;
2. The research project is approved as per the application form dated 20 June 2019 and the correspondence thereafter. Written permission from the Director: Animal Health must be obtained prior to any deviation from the conditions approved for this research project under this Section 20 permit. Please apply in writing to HerryG@daff.gov.za;
3. If required, an application for an extension must be made by the responsible researcher at least one month prior to the expiry of this Section 20 permit. Please apply in writing to HerryG@daff.gov.za;

4. No part of this research project may begin until the valid ethical approval has been obtained in writing from the relevant South African authority;
5. Pigs to be used in this research project may only be sourced from areas for which a state veterinary letter of no restriction has been provided to DAFF, i.e. the Gert Sibande District in Mpumalanga Province. It is the responsibility of the researcher to contact the responsible state veterinarian to ensure no restrictions have been placed on the area prior to sampling and to facilitate the issuing of veterinary movement permits if required;
6. Skin samples and faecal samples may be collected from the pigs mentioned above for the identification and analysis of internal and external parasites. Skin samples and any skin parasites must be killed on collection by placement in formalin or methylated spirits;
7. It is the responsibility of the researcher to obtain written consent from the owners of the pigs to be sampled in this research project, prior to such sampling occurring;
8. Samples must be packaged and transported in accordance with International Air Transport Association (IATA) requirements and/or the National Road Traffic Act, 1996 (Act No. 93 of 1996);
9. This research project must be conducted in compliance with the Veterinary and Para-Veterinary Professions Act 1982 (Act no 19 of 82);
10. It is the responsibility of the researcher and relevant laboratory or facility managers to ensure that the human safety aspects of this research project are adequately addressed;
11. Any incidence or suspected incidence of a controlled or notifiable disease in terms of the Animal Diseases Act 1984 (Act no 35 of 84), must be reported immediately to the state veterinarian of the area;
12. Please note that *Salmonella enteritidis*, *Salmonella gallinarum* and *Salmonella pullorum* are controlled diseases in South Africa. Any water samples positive for salmonella must be forwarded to a DAFF approved laboratory to confirm the presence or absence of these bacteria;
13. Any relevant foodborne pathogens identified must be reported to the Department of Health as required;
14. All potentially infectious material utilised or generated during or by the research project is to be destroyed at completion of the research project;
15. Only a registered waste disposal company may be used for the removal of all potentially infectious solid and liquid waste from the research project;
16. Records must be kept for five years for auditing purposes;

Title of research/study: Pig management under the free roaming system in the peri-urban areas of Mpumalanga Province, South Africa.
Researcher: Ms Priscilla Munzhelele
Institution: Parasitology, Mpumalanga Veterinary Services Laboratory, Ermelo; ARC-OVR, Onderstepoort
Permit Expiry date: 31 May 2021
Our ref Number: 12/11/1 (1237)
Your ref: 2019/CAES_HREC/108

Kind regards,

DR. MPHO MAJA
DIRECTOR OF ANIMAL HEALTH
Date: 2019 -08- 30

agriculture, land reform
& rural development

Department:
Agriculture, Land Reform and Rural Development
REPUBLIC OF SOUTH AFRICA

Directorate Animal Health, Department of Agriculture, Land Reform and Rural Development
Private Bag X138, Pretoria 0001
Enquiries: Ms Marna Laing • Tel: +27 12 319 7532 • Fax: +27 12 319 7470 • E-mail: MarnaL@dalrrd.gov.za
Reference: 12/11/1 (1237KL1)

Ms Priscilla Munzhelele
Nooitgedacht Agriculture Development Centre
Tel: 079 246 8769/ 071 403 0421/ 066 485 5294
Fax: 079 819 1223
E-mail: priscilla.munzhelele@gmail.com

Dear Ms Munzhelele

AMENDMENT OF SECTION 20 APPROVAL IN TERMS OF THE ANIMAL DISEASES ACT, 1984 (ACT NO 35 OF 1984) FOR: "*PIG MANAGEMENT UNDER THE FREE ROAMING SYSTEM IN THE PERI-URBAN AREAS OF MPUMALANGA PROVINCE, SOUTH AFRICA.*"

Your application dated 20 June 2019 for an amendment to a Section 20 permit refers.

The following amendment is hereby granted on the Section 20 permit with reference number 12/11/1 (1237) that was issued for the abovementioned study:

i) The expiry date of the Section 20 permit with reference number 12/11/1 (1237) is extended to 30 May 2024;

All other conditions as specified in Section 20 permit with reference number 12/11/1 (1237) remain in full effect.

Kind regards,

DR. MPHO MAJA
DIRECTOR: ANIMAL HEALTH
Date: 2021-05-21

Appendix 6: Proximate analysis results of the present study and for other published studies

	Different types of swill composition in this study				(Nayak, 2013)			(Westendorf *et al.*, 1999)	(Fung, 2019)				(Chae *et al.*, 2000)	(Myer *et al.*, 1999)	
Proximate principle (DM)	HS	SS	RS	WS	PSC	GM	PFB		SM	UDH	SW	FVW	DFW	DRFW1	DRFW2
Moisture %	80.14	80.27	54.36	56.63	11.0	11.0	11.0	73.00	61.08	60.85	82.89	90.50	-	11.4	8.4
DM %	19.86	19.73	45.64	43.37	89.0	89.0	89.0	27.00	38.92	39.15	17.11	9.50	-	88.6	91.6
CP %	12.90	16.09	23.61	38.70	20.0	18.0	16.0	20.8	25.51	18.90	24.39	9.17	25.00	15.0	14.4
ADF %	10.21	10.18	8.48	24.09	-	-	-	6.3	7.73	5.29	16.47	20.82	-	-	-
CF %	7.36	7.58	16.75	19.89	2.0	2.0	2.0	26.3	31.57	13.58	29.05	1.29	17.30	13.8	16.0
Ca %	0.31	1.49	2.89	0.81	0.6	0.6	0.6	0.92	0.98	0.25	0.28	0.38	1.37	0.54	0.63
Na %	0.24	0.85	0.40	0.11	0.5	0.5	0.5	1.04	0.77	0.85	-	-	3.28	0.35	0.47
P %	0.21	0.58	1.13	0.58	0.6	0.4	0.5	0.64	0.64	0.3	0.31	0.24	1.28	0.34	0.38
Ash %	3.36	11.28	9.50	7.02	8.0	8.0	8.0	6.2	7.73	5.01	3.47	5.06	18.07	5.8	4.7

Note: PSC = Pig starter creep, GM = Growth meal, PFB = Pig finisher & breeding meal, SM = Supermarket waste, UDH = University dining hall, CSM = Corn-soybean meal, NRC = National Research Council, FVW = Fruits and Vegetable Waste, DFW = Dried food waste, DRFW = Dehydrated restaurant food waste

Appendix 7: Language editing certificate

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Dear Professor Oguttu,

This letter confirms that I completed a language and content edit of a thesis entitled: **Free-roaming pig production in the peri-urban areas of Gert Sibande District in Mpumalanga province, South Africa: Husbandry practices, nutrition, and parasite burden**. This describes a research study conducted by Ms Priscilla Makungo under your supervision.

My edit included the following:

- Spelling and grammar
- Vocabulary and punctuation
- Adjusting the references for consistent presentation
- Linking concluding comments to study objectives

Thank you for providing me the opportunity to edit this excellent thesis.

Yours sincerely,



John Dewar (Professor)

11th August 2025

Appendix 8: First page of published article

J S Afr Vet Assoc. 2024;95:55-66
https://doi.org/10.36303/JSAVA.601
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J S Afr Vet Assoc
ISSN 2224-9435 EISSN 1019-9128
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ORIGINAL RESEARCH

Parasites burden in peri-urban free-roaming pigs in Gert Sibande District Municipality, Mpumalanga Province, South Africa

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Background: Parasite infections, unlike regulated animal diseases, do not often receive attention. In fact, parasites are major sources of financial losses in pig enterprises, particularly in subsistence and small-scale pig production systems.

Objective: To identify and quantify the prevalence of ecto- and endo-parasites among peri-urban free-roaming pigs (FRP) in Gert Sibande District Municipality (GSDM), Mpumalanga.

Method: Pig owners were identified using the snowball sampling method since no sampling frame for FRP farmers exists. Stratified sampling was used to select pigs for sampling for ecto- and endo-parasites. A form was used to record the observations. Pairwise correlation analysis was performed using Stata 15.0. The SPSS V28.0 statistical package was used to perform the chi-square test (X^2) to assess the distribution of parasites in different age groups. The prevalence of parasites was assessed in different age groups of pigs using multi-response crosstabs. Multivariate analysis of variance (MANOVA) was used to estimate the marginal mean of parasites according to municipality. Statistical significance was assessed at $\alpha \leq 0.05$.

Results: Over 90% (91.2%) of the pigs examined were infested with at least one parasite, including *Haematopinus suis, Sarcoptes scabiei*, *Ascaris suum*, *Fasciola hepatica*, *Trichuris suis*, *Strongylids*, *Coccidia* spp, *Moniezia expansa*, and *Siphonaptera* spp. The correlation between *Ascaris suum* and body condition was weak but statistically significant ($r = 0.24$; $p < 0.05$).

Conclusion: Policy makers, animal researchers and veterinary services must focus on developing policies, risk communication and community engagement materials, which target pig farmers in peri-urban areas such as Gert Sibande District Municipality, Mpumalanga Province.

Keywords: gastro-intestinal parasites, ecto-parasites, free-roaming pigs, disease, and zoonosis

Introduction

Pig farming has been recognised as a means of alleviating poverty, creating jobs, ensuring food security, providing a source of protein, and contributing to national GDPs (Adebisi 2008; Nonga & Paulo 2015; Odo et al. 2016; Nwafor et al. 2019). These recognitions are based on the fact that pigs have distinguishing traits, including rapid growth, excellent feed conversion, ease of housing and slaughter, need for smaller land area per unit, high fecundity, high protein content (pork), and ease of adaptation to diverse climatic situations. Despite the pig's outstanding performance, the pig industry is constrained by multiple yet overlooked challenges.

For many years, the South African pig industry has experienced numerous production-related and animal health issues with severe economic implications. Certain pig production systems used in the industry, particularly the extensive pig production system, act as catalysts for disease outbreaks. Such outbreaks may include, but are not limited to, classical swine fever (CSF), African swine fever (ASF) and salmonellosis. In the peri-urban areas of Mpumalanga Province (MP), including near human dwellings, open areas, along streams, and around garbage dumps, numerous pigs can be spotted roaming freely. In addition, a previous study conducted in MP confirmed that numerous pigs were slaughtered at home without the ante-mortem inspection by authorised veterinary services (Munzhelele 2015; Munzhelele et al. 2017; DCGTA, 2020). This situation portends high food safety and health risks to both humans and animals from the informal pig sector.

Parasitic diseases are commonly disregarded in smallholder pig farming, largely because unlike some rapidly spreading infectious diseases, parasitic diseases hardly cause enormous mortality. Furthermore, parasite infections, unlike regulated animal diseases, do not receive much attention in South Africa. Moreover, a high burden of parasite infestation can have severe negative economic impacts on the pig industry.

Ecto- and endo-parasites are major limitations to financial well-being and productivity in smallholder pig operation. In fact, previous research has shown that parasites have an ultimate effect on productivity and production outputs such as poor growth rate, litter size, low birth weight, reduced weight gain, poor feed conversion efficiency, decreased appetite, poor fertility, emaciation in pigs, condemnation of damaged organs