

**PREVALENCE AND RISK FACTORS ASSOCIATED WITH SELECTED
GASTROINTESTINAL PARASITES AMONG PIGS IN LAMWO
DISTRICT, UGANDA**

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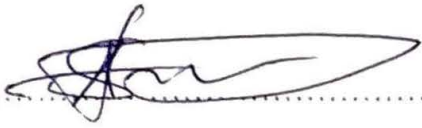
(Dip. APM; BVM; PGD-PPM)

**A Dissertation Submitted to the Directorate of Research and Graduate Training in
Fulfillment of the Requirement for the award of the Degree of Master of
Animal Production and Marketing of Gulu University**

October, 2025

Declaration

I, Avudraga Stanely, declare that this is my original piece of work and that it has never been submitted to any institution of higher learning for an academic award.

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Approval

This study was reviewed and approved by the Gulu University Research Ethics Committee (GUREC) with Approval number: GUREC-2024-841 under supervision, guidance, and approval from my supervisors.

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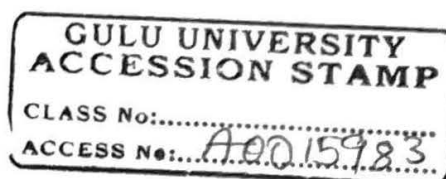
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Abbreviations

CGIAR	-	Consultative Group on International Agricultural Research
CI	-	Confidence Interval
EPG	-	Eggs Per Gram
FAO	-	Food and Agriculture Organization
GPI	-	Gastrointestinal Parasitic Infections
GPS	-	Global Positioning System
GUREC	-	Gulu University Research Ethics Committee
HH	-	Household
ILRI	-	International Livestock Research Institute
kg	-	Kilogram
LC	-	Local Council
LEO	-	Livestock Extension Officers
ml	-	Milliliter
MOU	-	Memorandum of Understanding
NaCl	-	Sodium Chloride
NDP	-	National Development Plan
PPE	-	Personal Protective Equipment
TC	-	Town Council
UBOS	-	Uganda Bureau of Statistics
µm	-	Micrometer

Abstract

Gastrointestinal parasitic infections (GPI) in pigs significantly reduce health and productivity, especially in smallholder systems. In Lamwo District, Uganda, data on GPI prevalence and risk factors are limited, hindering effective control efforts. In 2023, a cross-sectional study was conducted across six sub-counties in Lamwo District. A total of 266 pigs from 178 households were sampled. Fecal samples were analyzed using Faecal Sedimentation and Modified McMaster techniques to detect parasite eggs and oocysts. Data on household demographics, pig husbandry, water sources, sanitation, and environmental conditions were collected through structured questionnaires and observations. Statistical analyses including Chi-square tests, logistic regression, and Pearson correlation analysis were performed in R (version 4.4.1) to determine prevalence and identify risk factors at a 5% significance level. Seven gastrointestinal parasites species were identified. Strongyles were most prevalent (67.7%–80.4%), followed by *Fasciola* spp. (21.8%) and *Coccidia* spp. (9.3%–19.9%). Overall GPI prevalence was 74.1%, highest in Paloga Sub- County (13.9%) and lowest in Palabek Kal Town Council (10.2%). Key risk factors included feeding raw swill (AOR = 3.37–4.35; $p < 0.02$), free-ranging husbandry (AOR = 1.82; $p = 0.0226$), and exposure to human feces from open defecation (AOR = 0.87–2.48; $p < 0.03$). Local breeds were more affected than exotic or crossbreds. Access to piped or mixed water reduced infection risk. Land-use intensity also influenced infection (OR = 0.41; $p = 0.0003$). Correlation analysis showed moderate positive associations between GPI and both demographic ($r = 0.60$; $p = 0.005$) and husbandry factors ($r = 0.53$; $p = 0.000$). This study confirms a high burden of GPI in pigs in Lamwo District and highlights the critical role of poor husbandry, hygiene, and environmental factors in parasite transmission. Integrated, community-based control strategies including improved hygiene, better husbandry, farmer education, and veterinary interventions are essential to enhance pig health, boost productivity, and reduce zoonotic risks to local communities.

Chapter One: Introduction

1.1 Background

Globally, pig production is a rapidly growing livestock enterprise and an important contributor to food security, income generation, and poverty reduction, especially in developing countries. The world's pig population is estimated to exceed one billion, with the majority found in Asia and Europe (FAO, 2021). Pork remains one of the most consumed meats worldwide, accounting for about 36% of total meat consumption (FAO, 2021). Despite this global significance, pig production is constrained by a number of factors, notably parasitic infections, poor management practices, and limited access to veterinary services, which collectively reduce productivity and profitability (Ding & Kinnucan, 2011).

In Africa, pig production in Sub-Saharan Africa (SSA) has expanded steadily due to increasing urbanization and demand for affordable animal protein. The region's smallholder pig farmers dominate production, often raising pigs under low-input systems characterized by limited housing, inadequate feeding, and poor biosecurity (Roesel *et al.*, 2017). Consequently, gastrointestinal parasitic infections (GPI) remain widespread and are among the leading causes of morbidity and economic loss in pigs across SSA (Kungu *et al.*, 2019; Ngwili *et al.*, 2023). Common parasites such as *Ascaris suum*, *Strongyloides ransomi*, *Strongylus spp.*, *Coccidia spp.*, and *Fasciola spp.* are frequently reported in the region, impairing growth rates, causing weight loss, reducing feed conversion efficiency, and occasionally leading to death. Moreover, zoonotic parasites including *Taenia solium*, *Trichinella spiralis*, and *Toxoplasma gondii* remain a major public health concern in both rural and urban communities (Roesel *et al.*, 2017).

In Uganda, pig farming has grown remarkably over the past three decades, with the pig population increasing from approximately 0.7 million in 1990 to 7.1 million in 2021 (UBOS, 2024). This rise coincides with a growing per capita pork consumption of 3.4 kg, reflecting an increasing demand and presenting significant livelihood opportunities for pig-rearing households. Pig production has thus become a vital source of food, income, and manure for many rural communities (FAO, 2021; UBOS, 2024). Pigs offer competitive advantages over other livestock species due to their rapid growth rate, high fecundity, short generation intervals, quick financial returns, minimal space requirements, and popularity among women farmers, largely because they require less physical labor to manage (Roesel *et al.*, 2017).

However, despite these advantages, the piggery sector in Uganda remains underdeveloped. The majority of production occurs within traditional smallholder systems characterized by tethering, free-ranging, and feeding on raw garbage, kitchen waste, and agricultural by-products (Ngwili

et al., 2023; Sciences & Arvidsson, 2023). As a result, the productivity and profitability of rural pig enterprises lag behind those of intensive systems. This underperformance is mainly attributed to poor feed conversion ratios, high mortality, low reproductive rates, substandard product quality, and a heavy burden of production-limiting diseases such as gastrointestinal parasitic infections (Ding & Kinnucan, 2011; Kabirizi & Zziwa, 2014).

Previous studies in Uganda by Nsadhha *et al.* (2013), Kungu *et al.* (2019), and Roesel *et al.* (2017) have identified gastrointestinal parasitic infections as a prevalent problem among pig farmers, causing substantial economic losses and reduced productivity. Furthermore, zoonotic parasites such as *Taenia solium*, *Trichinella spiralis*, and *Toxoplasma gondii* not only affect animal health but also pose significant public health risks through pork consumption and poor sanitation practices.

In Lamwo District, like in many rural areas of northern Uganda, pig farming plays an increasingly important role in household livelihoods. However, the prevalence and distribution of gastrointestinal parasites in pigs remain poorly documented, despite their visible impact on productivity and public health. In light of these challenges, this study was designed to investigate the epidemiology of common pig gastrointestinal parasites in Lamwo District, focusing on *Coccidia*, *Strongylus* (red stomach worm), *Ascaris* (large roundworm), *Strongyloides* (threadworm), and *Fasciola* (liver fluke). Understanding these infections is critical for developing effective control measures, enhancing pig productivity, improving food security, and contributing to poverty reduction in Uganda and beyond.

1.2 Statement of the problem

Pig production holds considerable potential for poverty alleviation and job creation in rural Uganda. However, its growth is constrained by parasitic and endemic diseases that reduce productivity and increase economic losses (Muhanguzi *et al.*, 2012). Gastrointestinal parasitic infections (GPI) in pigs have been identified as a major production-limiting factor across several regions of Uganda (Roesel *et al.*, 2017; Ngwili *et al.*, 2023).

Globally, GPI have been estimated to cause economic losses ranging between US\$5 and US\$10 per pig annually due to reduced growth rates, poor feed conversion efficiency, stunted weight gain, reproductive failure, and increased mortality (FAO, 2021). In Sub-Saharan Africa, parasitic infections are responsible for up to 30–40% reductions in productivity, and in Uganda, studies have shown that infected pigs may take two to three months longer to reach market weight, leading to income losses exceeding UGX 40,000–80,000 per pig (Roesel *et al.*, 2017; Majalija *et al.*, 2023). These infections also increase treatment costs and contribute to condemnation of infected organs during slaughter, further reducing household income.

The prevalence and intensity of these infections are influenced by local production systems, environmental conditions, and socio-economic factors. Notably, the widespread reliance on free-range pig husbandry, combined with poor household sanitation and inadequate public health infrastructure, have been recognized as key risk factors for GPI in central, eastern, and western Uganda (Roesel *et al.*, 2017; Majalija *et al.*, 2023; Lagu *et al.*, 2017). These conditions are also common in Lamwo District (Ngwili *et al.*, 2022; 2023), suggesting that the area may be a hotspot for pig GPI.

Despite this, there is limited epidemiological data on the burden, distribution, and associated risk factors for gastrointestinal parasitic infections in pigs in Lamwo District. This lack of information hampers the development of effective, locally adapted control strategies. Therefore, an undertaking of the epidemiology of pig GPI to determine prevalence and risk factors is crucial to inform targeted interventions that can improve pig health, productivity, and ultimately rural livelihoods.

1.3 Objectives of the Study

1.3.1 General Objective

To investigate the prevalence and associated risk factors of selected gastrointestinal parasitic infections (GPI) in pigs in Lamwo District, Uganda.

1.3.2 Specific Objectives

- I. To identify the major gastrointestinal parasites affecting pigs in Lamwo District.
- II. To determine the prevalence of pig gastrointestinal parasitic infections in the study area.
- III. To determine the key risk factors associated with the occurrence of pig gastrointestinal parasitic infections in Lamwo District.

1.4 Justification and significance of the Study

Pig production is one of the fastest-growing livestock sectors in Uganda due to pigs' high fecundity, short generation intervals, and quick return on investment. It plays a vital role in improving household incomes, food security, and employment, particularly in rural areas. However, the development of this sector is hindered by limited farm-level investment in animal health and nutrition (Muhanguzi *et al.*, 2012), and by a high burden of production-limiting diseases such as gastrointestinal parasitic infections (GPI). These infections reduce growth rates, impair feed efficiency, increase mortality and treatment costs, and compromise animal welfare (Roesel *et al.*, 2017).

Although previous studies have explored GPI in other parts of Uganda, there is a lack of epidemiological data specific to Lamwo District, which is characterized by extensive free-

range pig production, inadequate sanitation, and limited access to veterinary services. These conditions are known risk factors for GPI, and their presence suggests that Lamwo may be a potential hotspot for infection (Ngwili *et al.*, 2022 & 2023). Without localized data, designing effective and context-specific interventions remains challenging.

This study is timely and aligns with Uganda's Third National Development Plan (NDP III), which prioritizes the development of livestock value chains and agro-industrialization (National Planning Authority, 2020). Addressing GPI will contribute to improved pig productivity, food safety, and rural livelihoods. Moreover, controlling GPI including zoonotic parasites like *Fasciola spp.* and *Taenia solium* will reduce public health risks. The findings provide critical baseline data to inform evidence-based interventions for parasite control in Lamwo District and similar rural settings.

1.5 Scope of the Study

The study was limited to describing the distribution of parasites, estimating their prevalence, and identifying associated risk factors. It did not include clinical diagnosis or treatment, cost-benefit analysis of control measures, or molecular identification of parasites. Being a cross-sectional study, it provides a snapshot of the GPI status during the study period and does not capture seasonal variations or long-term trends. The findings are intended to inform targeted parasite control strategies and enhance pig health and productivity in Lamwo District and similar production environments.

1.6 Research Questions

- I. What are the predominant gastrointestinal parasites infecting pigs in Lamwo District?
- II. What is the prevalence of gastrointestinal parasitic infections among pigs in Lamwo District?
- III. Which household, husbandry, and environmental factors are significantly associated with pig GPI in Lamwo District?

1.7 Conceptual framework

This conceptual framework presents the key factors influencing the prevalence of gastrointestinal parasitic infections (GPI) in pigs in Lamwo District. It is derived from both empirical evidences gathered in this study and existing literature on parasite epidemiology. The framework organizes the influencing variables into four main domains: Pig-Level Factors, Management Practices, Household Factors, and Environmental Factors each contributing directly to the outcome.

Intervening factors such as access to veterinary services and community awareness modify these relationships, while confounding factors like sub-county location, history of parasite exposure, and the presence of other livestock species may distort observed associations. Key findings from this study such as the strong association between raw swill feeding (OR = 4.354), free-ranging systems, and poor sanitation are incorporated into the framework to reflect context-specific realities. The framework therefore serves both as a guide for interpreting findings and as a basis for targeted intervention planning.

Illustrates the relationships among pig-level, management, household, environmental, intervening, and confounding factors and their influence on the prevalence of gastrointestinal parasitic infections.

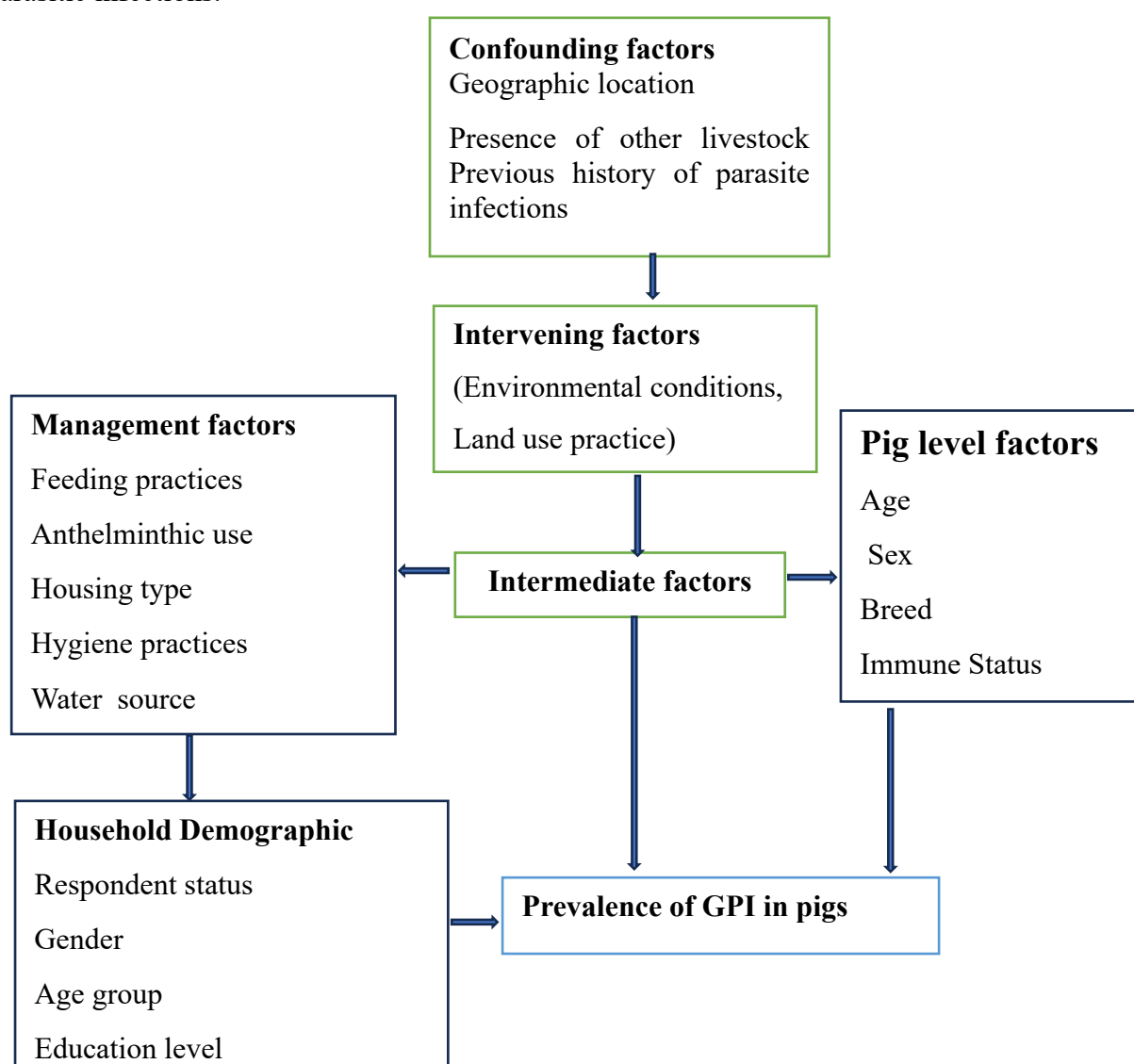


Figure 1: Conceptual Framework of Factors Influencing GPI in Pigs in Lamwo District

1.8 Significance of the study

This study generates critical epidemiological insights into the prevalence and risk factors associated with gastrointestinal parasitic infections (GPI) in pigs within Lamwo District. Given the limited data available in this region, the findings provide an evidence base to inform targeted interventions for controlling GPI in smallholder pig production systems.

By identifying major GPI and their associated risk factors, the study contributes to improved animal health management, enabling more effective disease prevention strategies. Reducing the incidence of GPI is expected to lower treatment costs, reduce mortality, and enhance pig welfare, ultimately increasing productivity and income for smallholder farmers. Furthermore, the study addresses important public health concerns, as some GPI may pose zoonotic risks, especially in communities with poor sanitation and close human-animal interactions.

The outcomes of this research will be valuable to veterinary practitioners, extension agents, and policymakers in designing sustainable GPI control programs that promote resilient and profitable pig farming in Northern Uganda

Chapter Two: Literature Review

2.1 General Information

Gastrointestinal parasitic infections (GPI) in pigs are caused by a variety of parasite genera that significantly impact pig health and production. GPI result in digestive disturbances, loss of appetite, poor growth, reduced feed efficiency, and can lead to organ and carcass condemnation. These infections increase treatment costs and economic losses and, in severe cases, may cause mortality (Pinilla *et al.*, 2020). The parasites responsible for GPI are mainly from the phyla Nematoda (roundworms) and Platyhelminthes (flatworms), including classes Trematoda (flukes) and Cestoda (tapeworms) (Taylor *et al.*, 2015). Protozoan parasites such as *Eimeria* spp. and *Cystoisospora suis* also contribute to GPI by causing diseases such as swine coccidiosis, which primarily affects piglets under three months old (Bohach *et al.*, 2023).

Common nematode species *Ascaris suum*, *Trichuris suis*, *Strongyloides ransomi*, and members of the order Strongylida reduce feed efficiency, cause nutrient malabsorption, and provoke organ inflammation due to larval migration. Severe infections often result in emaciation and persistent diarrhea (Tumusiime *et al.*, 2020). Some protozoans, including *Balantidium coli*, *Entamoeba coli*, and *Cryptosporidium* spp., pose zoonotic risks to humans, emphasizing the public health importance of GPI (Pinilla *et al.*, 2020).

2.2 Etiology of Gastrointestinal parasitism in pigs

The etiology of GPI in pigs is complex and involves diverse parasite species with lifecycles that commonly include ingestion of infective eggs or larvae from contaminated feed, water, or soil (Anteneh *et al.*, 2008; Schwartz, 1952).

Upon ingestion, parasites such as *Strongyloides ransomi* and nodular worms (*Oesophagostomum* spp.) penetrate the intestinal wall, causing localized tissue damage and inflammation. Other parasites, including *Ascaris suum* and *Trichuris suis*, migrate through organs such as the liver and lungs before returning to the intestines to mature into adults (Mukrimaa *et al.*, 2016).

Within the intestines, parasites develop into adult worms, which may attach to the intestinal mucosa or induce nodules in the large intestine, depending on species (Roepstorf & Nansen, 1998).

Protozoan parasites like *Isospora suis* and *Eimeria* spp. release sporozoites from ingested oocysts that invade intestinal epithelial cells, developing intracellularly and causing epithelial damage characteristic of coccidiosis (de Araújo *et al.*, 2020).

This figure illustrates the lifecycle stages of key gastrointestinal parasites in pigs, showing egg ingestion, larval migration through organs, maturation to adult worms in the intestines, and shedding of eggs/oocysts into the environment (illustration by William P. Hamilton CMI).

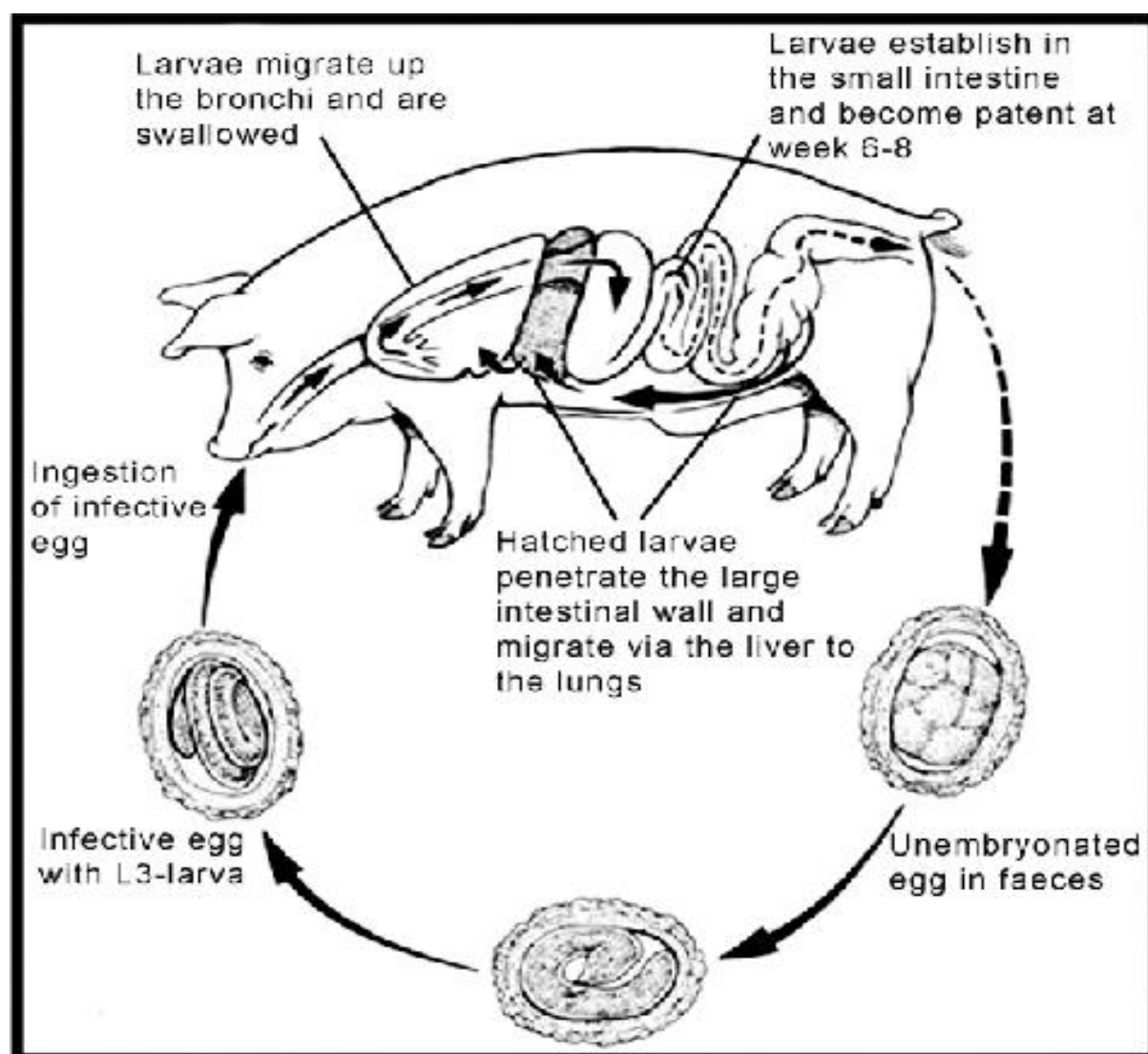


Figure 2: Lifecycle of Common Pig Gastrointestinal Parasites

2.3 Geographical distribution

The prevalence and distribution of pig GPI vary according to climatic conditions, farming practices, animal management, and regional parasite exposure and control measures.

Globally, *Ascaris suum*, *Trichuris suis*, and *Oesophagostomum* spp. are common in Europe, Asia, and America (Rinaldi *et al.*, 2011; Charlier *et al.*, 2014). In Sub-Saharan Africa, West Africa reports high prevalence of *Ascaris suum*, *Strongyloides ransomi*, and *Taenia solium*, which causes taeniasis and cysticercosis. East Africa shows a similar nematode burden, with *Fasciola* spp. more common in areas with suitable snail habitats, while Southern Africa experiences varying prevalence depending on veterinary infrastructure and deworming programs (Nwafor *et al.*, 2021; Kagira *et al.*, 2012; Gebreyesus *et al.*, 2015; Ajayi *et al.*, 2018).

In Uganda, studies reveal a high prevalence of pig GPI. Roesel *et al.* (2017) identified nematodes such as *Ascaris suum*, *Strongyloides ransomi*, and *Oesophagostomum spp.* as prevalent across the country, highlighting their negative effects on pig health and productivity. Ngwili *et al.* (2023) corroborated these findings and noted regional differences influenced by climate, farming practices, and veterinary service availability. In Northern Uganda, Odongo *et al.* (2017) reported *Ascaris suum*, *Trichuris suis*, and *Strongyloides ransomi* as predominant

2.4 Burden of Pigs Gastrointestinal Parasites

Most pigs in Uganda experience free-range or scavenging conditions, increasing their exposure to gastrointestinal parasites. Although worm burdens have not been extensively quantified, clinical signs such as stunted growth, poor weight gain, and ascites are frequently observed. Infected pigs are more susceptible to other diseases due to weakened health.

Parasitic infections cause pathological changes, including heavier and damaged organs (lungs and liver), which reduce meat quantity and quality at slaughter. For instance, *Ascaris suum* causes liver lesions, and *Trichuris suis* damages intestinal tissues, both contributing to economic losses for farmers (de Silva, Brooker *et al.*, 2003).

2.5 Risk Factors of Pig Gastrointestinal Parasitism

Key factors contributing to pig GPI include poverty, poor hygiene and sanitation, inadequate latrine use, free-range grazing systems, irregular or absent deworming, and allowing pigs to scavenge on human feces. Additionally, poor nutrition weakens immune responses, increasing the severity of infections even at low parasite burdens (Alarakol *et al.*, 2020; Eshitera *et al.*, 2012).

2.6 Prevention and Control of Pigs Gastrointestinal Parasites

Control measures for pig GPI in Uganda primarily involve sporadic deworming, guided by veterinary advice. Commonly used anthelmintics include Wormcid® (Levamisole) tablets and injectable drugs such as Ivermectin, which also controls mange.

Studies suggest that combined drug treatments (e.g., Praziquantel, Niclosamide, Albendazole) alongside improvements in sanitation, latrine use, and husbandry practices can significantly reduce parasite transmission, despite challenges in implementation (De Coster *et al.*, 2018).

2.7 Diagnosis of Gastrointestinal Parasites in Pigs

2.7.1 Macroscopic visualization in pigs

Adult gastrointestinal parasites like *Ascaris suum*, *Oesophagostomum spp.*, and *Trichuris suis* are large enough to be visible to the naked eye. Their presence in feces, necropsy, or slaughter

confirms infection. However, absence of visible worms does not rule out infection, as immature parasite stages require microscopic identification (Vlaminck *et al.*, 2014).

2.7.2 Faecal Examination

Fecal analysis methods include qualitative identification of parasite species based on egg or oocyst morphology and quantitative methods measuring infection intensity via eggs or oocysts per gram of feces (EPG/OPG). The choice depends on clinical objectives, sample type, and available resources.

2.7.3 Faecal Floatation

This technique utilizes the difference in density between parasite eggs or oocysts and fecal debris. Eggs and oocysts float in solutions with specific gravity between 1.10 and 1.20, facilitating microscopic identification. The modified McMaster technique quantifies EPG/OPG by counting eggs or oocysts within a known sample volume (Coles *et al.*, 1992; Taylor *et al.*, 2016).

2.7.4 Faecal Sedimentation

This method relies on sedimentation of heavier parasite eggs or oocysts in solutions with specific gravity lower than the eggs, often with solvents like ether. After settling, the sediment is examined microscopically to detect parasites that do not float well in flotation solutions (Taylor *et al.*, 2016; Soares *et al.*, 2020).

Chapter Three: Materials and Methods

3.1 Study area

This study was part of a larger research project by the International Livestock Research Institute (ILRI) aimed at developing control interventions against zoonotic *Taenia solium* infections in Agago, Lamwo, Pader, and Kitgum districts in Northern Uganda.

The study was conducted in Lamwo District, situated in the Acholi sub-region of Northern Uganda. The district was selected due to its convenience and the presence of key risk factors for gastrointestinal parasites, including high pig density, poverty, and poor sanitation. Lamwo is predominantly rural, with most residents practicing subsistence smallholder farming, which relies heavily on livestock production, particularly pig rearing.

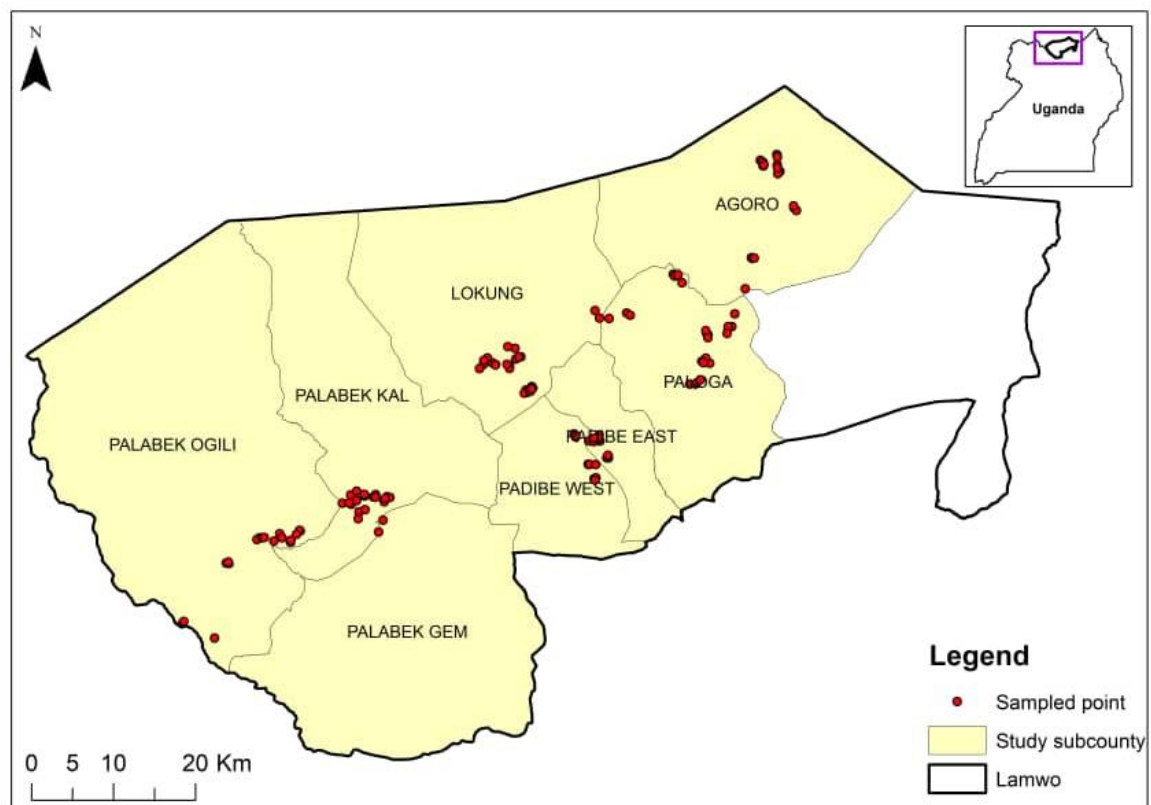


Figure 3: Map showing the study area

3.2 Study design

A This study employed a cross-sectional design, which involves collecting data at a single point or over a short specific period in time to determine the prevalence of a condition and its associated risk factors within a defined population. The design was chosen because it allows for the simultaneous assessment of both the presence of gastrointestinal parasite infections in pigs and the risk factors that may influence their occurrence under existing farm management conditions.

The cross-sectional study was conducted from May to December 2024. During this period, faecal samples were collected from pigs, and corresponding questionnaire data on potential risk factors were obtained from pig-rearing households in the selected villages of Lamwo District. This design was appropriate as it provided a snapshot of the epidemiological situation of gastrointestinal parasites in the study area, enabling estimation of their prevalence and identification of associated factors.

3.3 Study population

Data were collected from pigs and pig farmers, with the unit of analysis being the pigs and the units of observation comprising samples collected from pigs and responses from the farmers. Lamwo District, which has 12,585 pigs and 4,839 pig-rearing households, with an average herd size of 3.3 pigs per household (Statistics, 2024), was the focus of this study.

3.4 Inclusion and exclusion criteria

Households were included in the study if they raised pigs at the time of the research, had at least one eligible pig (defined as a pig that was at least three months old, in good health, and not pregnant), and provided informed consent. Pigs younger than three months, pregnant pigs, or those in poor health were excluded to minimize stress-related risks and ensure the safety of faecal sample collection.

3.5 Sample size determination

The sample size was calculated using the formula adapted from Naing *et al.*, (2022).

$$n = \frac{Z^2 P(1 - P)}{d^2}$$

Where:

N = the required number of samples,

Z = the Z statistic for the level of confidence,

d = the standard allowable error (precision level), set at 5% (equivalent to 0.05),

P = the estimated prevalence, which was set at 12.7% (0.127) as reported by Oba *et al.* (2023) in Lira District, Northern Uganda, due to the absence of previous studies in Lamwo District, and $1-P$ = the probability of not having the disease.

Based on these parameters, the initial calculated sample size was 270 pigs. To account for potential non-responses, the formula for adjustment was applied:

$n^1 = \left(\frac{n}{1-r} \right)$, Where: n = the initially calculated sample size (270), r = the non-response rate (2%, equivalent to 0.02), and n^1 = the adjusted sample size.

After adjustment, the total sample size was 276 pigs. These were sampled from six (6) out of the twelve (12) sub-counties in Lamwo District. To minimize clustering, two or more pigs that met the selection criteria were sampled per household.

3.6 Sampling procedure

The district was selected based on convenience, the presence of risk factors for gastrointestinal parasites reported by ILRI's BUILD Uganda project (November 2021), and data from spatial risk maps (2001–2016) that highlight areas where poverty, poor sanitation, and high pig density overlap (Ngwili *et al.*, 2023). Lamwo District was purposively selected because of its high pig population density, limited prior parasitological research, and its representation of typical smallholder pig production systems in Northern Uganda.

Lists of villages per sub-county were obtained from the respective Lower Local Governments with assistance from the District Planner. Six villages per sub-county were then randomly selected using the Microsoft Excel RAND function.

Within each selected village, five pig-keeping households were randomly chosen using the Randomizer App, based on lists of pig-rearing households provided by Local Council One Chairpersons, with the support of veterinary extension workers. This process resulted in a maximum of 30 pig farmers per sub-county and a total of 178 pig-rearing households across the district from the six sub-counties.

In each selected household, up to two pigs were sampled, yielding a maximum sample size of 360 pigs for the district. Additionally, all participating pig-rearing households were included in a risk factor analysis.

In cases where a household declined to participate, had no eligible pigs, or where pigs could not be captured, the field team conducted randomized selection of replacement households from the remaining list. If five qualifying households could not be identified within a village, additional households were selected from nearby villages.

Out of 180 targeted households, 178 were sampled across 48 villages within 6 sub-counties. The number of samples collected per village ranged from 1 to 10 pigs, involving between 1 to 5 households per village. After excluding 2 pigs due to incomplete data, the total sample size was 266 pigs. Pig-owning households were selected through a multistage sampling approach.

Within each randomly selected village, lists of pig-rearing households were obtained from Local Council I Chairpersons, and simple random sampling was applied using the Randomizer App to ensure that all eligible households had an equal chance of selection.

Table 1: Sampled sub-counties, parishes and villages

Sub-counties	Parish	Villages
Palabek Ogili	Apyetta	Apyetta Central, Apyetta West
	Lugwar	Layamo
	Akworo	Akworo Central, Lagot Padwat
	Ogili	Lagot Opuk
Paloga	Bungu	Oboke Olot
	Pawaja	Marakac A, Ongalo, Kaliro
	Paloga	Atangwa, Paloga Central
Palabek kal TC	Bwomono	Lugolo, Guruguru
	Labigiryang	Alimotiko East
	Kal	Kal Central B
	Lanywang	Waragiri, Karatum
Padibe TC	Mura	Palaa Central
	Gangdyang	Ngomoromo Central
	Kuluyee	Kakira North, Doglokutu West
	Atwol	Bwola
	Kamama	Nyomalo East
Lamwo TC	Ocula	Ocula Central
	Atiba	Cinkul
	Olebi	Lokung Trading Center
	Ogwec	Juba, Ongalo, Ateda
Agoro	Pobar	Goloro C
	Rudi	Lugede
	Lorunya	Agula Odiciri B
	Lopulongi	Polocire East
	Laruc	Lorumbenge B
	Ngacino	Obere B

3.7 Sample collection

During sample collection, pigs were handled humanely and minimally restrained by their owners under the supervision of trained animal health assistants to ensure animal welfare. Fecal samples were collected non-invasively, either from the rectum using lubricated gloves or from freshly voided feces.

To ensure effective data gathering and adherence to safety protocols, careful coordination and planning were conducted before sample collection, including a meeting with the Chief Administrative Officer of Lamwo District to discuss the research activities, obtain necessary approvals, and clarify field entry requirements. Collaboration and supervision by the ILRI team ensured alignment of study objectives, sampling protocols, and the assignment of specific roles and responsibilities, while local assistants supported animal care.

The materials necessary for sample collection, including sterile sample containers, disposable gloves, lubricants, spatulas, cooler boxes, ice packs, and disinfectants, were provided by ILRI. All team members were equipped with appropriate protective gear and adhered to strict hygiene and safety protocols throughout the process.

Faecal samples were collected from eligible pigs by either directly obtaining the sample from the rectum or by gathering fresh manure from the floor of the pen. Approximately 5 grams of faecal matter were collected per pig and placed in BD Falcon™ 50-ml conical tubes, which were labeled with relevant details such as the date, animal ID, sex, age of the pig, and household identifier number. These samples were then stored in an insulated cooler at 4°C and transported to the Kitgum District Veterinary Laboratory for analysis.

In addition to faecal sample collection, household surveys and questionnaires were administered to gather comprehensive data on pig farming practices. The questionnaire was pre-tested in Larom East and West Villages to ensure clarity and effectiveness. Data collected included demographic characteristics of respondents, details on pig production and management systems (e.g., free-range or intensive), hygienic practices, and knowledge regarding gastrointestinal parasites in pigs. Responses were entered into the ILRI Open Data Kit (ODK), and only households meeting the inclusion criteria for pig ownership were surveyed. The questionnaire captured additional information on pig breed types (local, exotic, and crossbreeds) and management systems (free-range, semi-intensive, and intensive) to support assessment of potential risk factors associated with gastrointestinal parasite infections.

Observations were also made as a supplementary data collection method. These observations focused on the environmental conditions, pig farming practices, offering insights into management systems, hygiene practices, and other factors relevant to the prevalence of gastrointestinal parasites. To facilitate the analysis of the geographical distribution of parasites, GPS coordinates of each homestead were recorded.

Environmental variables were incorporated into the dataset using QGIS (see Appendix Table 1). Data on average rainfall, land use cover, normalized difference vegetation index (NDVI),

altitude, slope, and soil type were extracted from secondary sources and added to the study. A buffer zone of 300 meters around each household was created, and raster files were overlaid in QGIS to extract relevant environmental data for each household buffer. This data was used to analyze the potential influence of environmental factors on the distribution and prevalence of gastrointestinal parasites in Lamwo District (See Appendix 11).

3.8 Sample Packaging, Storage, and Transportation

Each sample was sealed in a labeled sterile container, wiped clean, and placed in a leak-proof bag. They were kept cool at 4°C in a cooler box with ice packs during transport. Upon arrival at the Kitgum District Diagnostic Laboratory, the samples were stored at 4°C and analyzed within 24 hours to maintain accuracy

3.9 Laboratory analysis of samples

The laboratory analysis used two methods, faecal sedimentation and the Modified McMaster Standard Operating Procedures (S.O.P), to accurately quantify parasite eggs and assess parasite load for further analysis. Two diagnostic methods sedimentation and Modified McMaster were employed to ensure comprehensive detection and quantification of parasite eggs. Sedimentation was particularly suitable for identifying heavier eggs such as *Fasciola spp.*, which may not float during flotation-based techniques.

3.9.1 Faecal sedimentation

Approximately 3 grams of faecal matter were mixed with 200 ml of water to create a suspension, then strained to remove debris. Liquid detergent was added to help release parasite eggs, and the mixture was left to settle for 10-20 minutes. The clear supernatant was decanted, and the sediment was transferred to a petri dish for microscopic examination. Parasite eggs were identified, counted, and recorded for further analysis.

3.9.2 Modified McMaster S.O.P (Egg Quantification Test)

A precise 4 grams of faecal matter was mixed with 56 ml of saturated NaCl solution to create a 60 ml suspension. The mixture was sieved to remove larger particles, and the suspension was transferred to a McMaster chamber to settle for 5 minutes. Parasite eggs were counted under a light microscope, and the number of eggs per gram of faeces was calculated. Observations on egg types and densities were recorded, and the results were analyzed to assess parasite burden and infection levels. Infection status was determined based on microscopic identification of parasite eggs and oocysts, recorded as either positive or negative for each pig. Morphological identification was chosen as it remains a reliable, cost-effective, and widely accepted diagnostic method in field parasitology, suitable for resource-limited settings (Slusarewicz, *et al.*, 2021).

3.10 Data quality control and safety

Strict aseptic techniques were followed, including daily disinfection of work surfaces with 70% ethanol and 1% sodium hypochlorite, to maintain a sterile environment; samples were transported and stored at 4°C with the help of ice packs and coolers; all team members wore PPE, including gloves and lab coats, to ensure safety and prevent contamination; negative and positive controls were used during analysis to minimize errors and improve accuracy; expiry dates of laboratory consumables were carefully monitored to avoid using expired materials; and data from surveys and sample analysis were recorded in the ILRI Open Data Kit (ODK), ensuring reliable data collection for further analysis.

3.11 Data cleaning and management

The data was organized and merged using the dplyr package in R. Validation for discrepancies, outliers, missing values, and errors was carried out to ensure data quality. Variable names were standardized, duplicates removed, and outliers addressed systematically, with transformations applied where necessary to meet analysis requirements. All modifications were documented for transparency, and the cleaned data was securely stored with backups. The final datasets were exported to Stata software for analysis, employing statistical tests such as Chi-square and calculating prevalence rates with a 95% confidence interval to provide robust insights into associated risk factors. All statistical analyses were conducted at a 95% confidence level to ensure robust inference of associations between gastrointestinal parasite prevalence and identified risk factors.

3.12 Data Analysis

Data from faecal examinations, pig biodata, and questionnaires were combined to generate a dichotomous outcome variable indicating the presence or absence of gastrointestinal parasites. Descriptive statistics were used to summarize the data and identify anomalies. Chi-square tests were conducted to assess associations between categorical variables, such as parasite prevalence and management practices. Mixed-effects logistic regression, with households as random effects, was used for univariable analysis. Continuous predictors' linearity was assessed using Lowess curves and quadratic terms (Creswell, 2018). Variables with $p < 0.5$ were retained for multivariable modeling, focusing on households as the random effect due to small sub-county variance.

The dependent variable in the analysis was the presence or absence of gastrointestinal parasites in pigs. Independent (covariate) variables included pig-level factors (age, sex, breed), management factors (feeding system, housing, hygiene, water source and quality), and environmental variables (rainfall, NDVI, soil type, and land use).

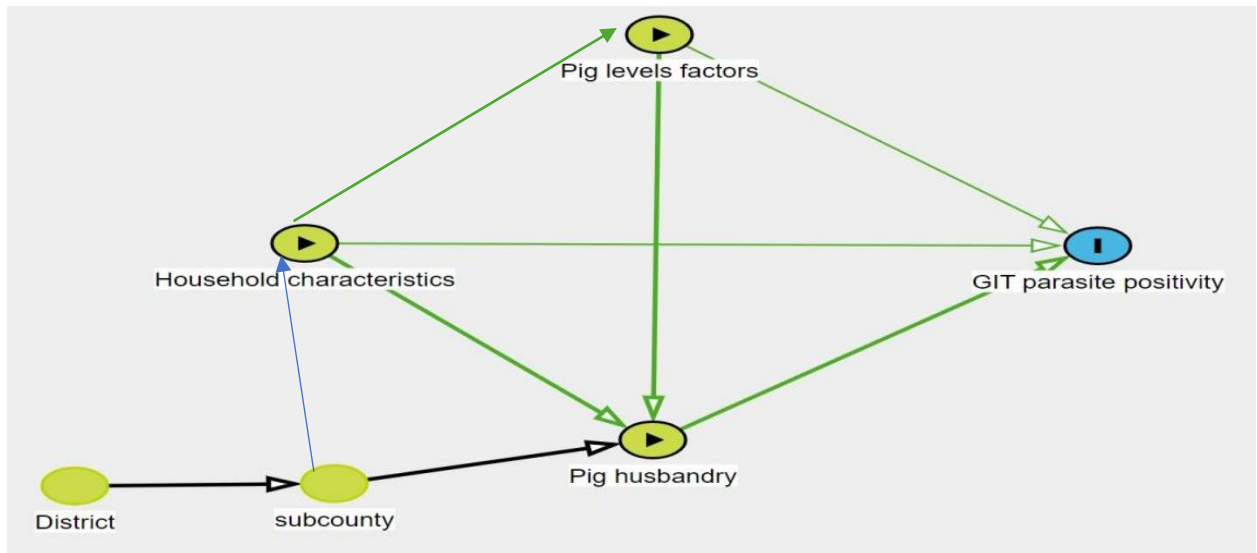


Figure 4: Directed Acyclic Graph (DAG) as a causal diagram for identification of risk and confounding factors associated with gastrointestinal parasite infections in Pigs

The causal diagram illustrates hypothetical causal relationships, where management factors affect pig-level variables, but pig-level factors (age, sex, breed) do not influence management practices. Confounding factors, such as sub-county and household characteristics, were controlled to isolate the direct effects of management practices on infection outcomes, excluding intervening variables.

To control for confounding factors such as sub-county and household characteristics, Multivariable Logistic Regression Analysis was used. This approach allowed for the adjustment of multiple variables simultaneously, ensuring that the estimated effects of management practices on infection outcomes were not biased by other influencing factors. The model included key covariates identified through a Directed Acyclic Graph (DAG) to prevent the inclusion of mediating variables. The mixed-effects logistic regression model applied in this study is a form of multivariable logistic modeling that incorporates both fixed and random effects to account for clustering within households. By incorporating household-level random effects, variability within households was accounted for, reducing potential biases. Also, interaction terms were examined to assess whether specific household or sub-county characteristics modified the effects of management practices on infection outcomes. Both water quality and water source were considered distinct but related risk factors, with quality referring to the cleanliness or contamination level, and source referring to the type of water accessed.

3.13 Study limitations and mitigations

Challenges such as false socio-demographic data, financial constraints, language barriers, and animal handling risks were addressed through briefings, collaboration with local leaders and

ILRI, practical budgeting, communication in Luo (Achoi), and adherence to proper animal handling protocols.

Diagnostic accuracy was maximized by following standardized laboratory protocols and using positive and negative controls, which helped minimize false positives and false negatives. The history of previous infections was based on farmer recall, which may be affected by recall bias; this was acknowledged as a study limitation.

3.14 Ethical considerations

This research was part of a broader International Livestock Research Institute (ILRI) project in Northern Uganda. Ethical clearance was obtained from ILRI's Institutional Research Ethics Committee (IREC-ILRI-IREC2022-66), ILRI Institutional Animal Care and Use Committee (ILRI-IACUC2022-44), ILRI Institutional Biosafety Committee (ILRI-IBC2022-28), and the School of Veterinary Medicine and Animal Resources, Research Ethics Committee–Institutional Animal Care and Use Committee, Makerere University (SVAR_IACUC 136/2022). A research permit from the Uganda National Council for Science and Technology (UNCST) was also obtained (A263ES). In addition, the study received approval from the Gulu University Research Ethics Committee (GUREC) (Approval number: GUREC-2024-841).

3.15 Research dissemination plan

Research findings were disseminated through peer-reviewed manuscripts, stakeholder engagements with government structures, and educational workshops. Farmers and local authorities received training on parasite management, prevention, and monitoring. Collaboration with ILRI addressed the economic impacts of parasitic infections and supported strategies to safeguard livelihoods and promote sustainable livestock farming

Chapter Four: Results

4.1 Household Demographics, Pig Characteristics, Husbandry, and Sanitation Practices

Distribution of households and pigs sampled

Table 2 presents the distribution of sampled units by location. Palabek Kal Town Council (TC) recorded the highest number of HH (n = 30; 16.9%) and pigs (n = 49; 27.5%). Paloga Sub-County followed with 27 HH (15.2%) and 39 pigs (21.9%), while Palabek Ogili Sub-County accounted for 25 HH (14.0%) and 37 pigs (20.8%). Both Padibe TC and Lamwo TC each contributed 26 HH (14.6%), with 36 pigs (20.2%) and 37 pigs (20.8%) sampled, respectively. Agoro Sub-County had the lowest representation, with 18 HH (10.1%) and 25 pigs (14.0%).

Table 2: Distribution of HH and Pigs Sampled by Location

Sub-counties	Parish	Villages	Number of HH		Number of pigs	
			(n)	(%)	(n)	(%)
Palabek Ogili	Apyetta	Apyetta Central, Apyetta West	7	3.9	10	5.6
	Lugwar	Layamo	4	2.2	6	3.4
	Akworo	Akworo Central, Lagot Padwat	9	5.1	12	6.7
	Ogili	Lagot Opuk	5	2.8	9	5.1
Paloga	Bungu	Oboke Olot	4	2.2	6	3.4
	Pawaja	Marakac A, Ongalo, Kaliro	15	8.4	19	10.7
	Paloga	Atangwa, Paloga Central	8	4.5	14	7.9
Palabek kal TC	Bwomono	Lugolo, Guruguru	10	5.6	16	9.0
	Labigiryang	Alimotiko East	5	2.8	10	5.6
	Kal	Kal Central B	6	3.4	10	5.6
	Lanywang	Waragiri, Karatum	9	5.1	13	7.3
Padibe TC	Mura	Palaa Central	5	2.8	6	3.4
	Gangdyang	Ngomoromo Central	5	2.8	7	3.9
	Kuluyee	Kakira North, Doglokutu West	6	3.4	9	5.1
	Atwol	Bwola	5	2.8	7	3.9
	Kamama	Nyomalo East	5	2.8	7	3.9
Lamwo TC	Ocula	Ocula Central	5	2.8	8	4.5
	Atiba	Cinkul	5	2.8	6	3.4
	Olebi	Lokung Trading Center	5	2.8	7	3.9
	Ogwec	Juba, Ongalo, Ateda	11	6.2	19	10.7
Agoro	Pobar	Goloro C	1	0.6	2	1.1
	Rudi	Lugede	4	2.2	6	3.4
	Lorunya	Agula Odiciri B	2	1.1	2	1.1
	Lopulongi	Polocire East	4	2.2	4	2.2
	Laruc	Lorumbenge B	4	2.2	6	3.4
	Ngacino	Obere B	3	1.7	5	2.8

Source: Researcher, 2024

Demographic Characteristics of Respondents

As shown in Table 3, out of the 178 HH surveyed, 52.2% of the respondents were HH heads, while 47.8% were delegated representatives. Males accounted for 60.7% of respondents, while females constituted 39.3%. The majority of respondents (56.7%) were aged 39 years or below. In terms of education, 59.0% had attained primary education or below, whereas 41.0% had education above the primary level.

Table 3: Demographic Characteristics of Respondents (n = 178)

Characteristic	Category	Number (n)	Percentage (%)
Respondent Status	HH head	93	52.2
	Delegated representatives	85	47.8
Gender	Male	108	60.7
	Female	70	39.3
Age group	39 years or below	101	56.7
	Above 39	77	43.3
Education level	Primary education or below	105	59.0
	Above primary education	73	41.0

Source: Researcher, 2024

Characteristics of Pigs Sampled

A total of 266 pigs were sampled across the study locations. As summarized in Table 5, the majority were female (n = 170; 63.9%) and below 7 months of age (n = 139; 52.3%). In terms of breed, local pigs predominated, representing 73.7% (n = 196) of the total sample. Crossbreeds accounted for 20.3%, while exotic breeds made up only 6.0%.

Table 4: Characteristics of Sampled Pigs by Sex, Age group, and Breed (n = 266)

Variables	Category	Number (n)	Proportion (%)
Sex	Male	96	36.1
	Female	170	63.9
Age group	Less than 7 months	139	52.3
	7 months or older	127	47.7
Breed	Local	196	73.7
	Crossbreed	54	20.3
	Exotic	16	6.0

Source: Researcher, 2024

Pig Husbandry and Sanitation Practices Among Surveyed Households (HH):

The majority of HH (n = 158; 88.8%) practiced year-round free-range scavenging, with most pigs (n = 234; 88.0%) also kept under this system. Feeding mainly relied on fodder and crop residues among (n = 131; 73.6%) HH, while (n = 75; 42.1%) combined these with commercial feeds. Only (n = 15; 8.4%) HH relied solely on commercial feeds. Brewer's waste was used by (n = 92; 51.7%) HH, and scavenging for feed was common among (n = 121; 68.0%) HH. Boreholes served as the main water source for (n = 154; 86.5%) HH, while only (n = 50; 28.1%) HH practiced deworming.

Table 5: Pig Husbandry Practices Among Surveyed Households (HH)

Practice category and specifics	Households not using the practice				Households using the practice			
	Households represented		Number of pigs owned		Households represented		Number of pigs owned	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Production system								
Scavenging all time	20	11.2	32	12.0	158	88.8	234	88.0
Scavenging - dry season only	21	11.8	157	59.0	157	88.2	109	41.0
Scavenging - wet season only	142	79.8	227	85.3	36	20.2	39	14.7
Sourcing feed								
Fodder and crop residues	47	26.4	65	24.4	131	73.6	201	75.6
Commercial feeds + fodder	103	57.9	157	59.0	75	42.1	109	41.0
Commercial feeds only	163	91.6	243	91.4	15	8.4	23	8.6
Swill	156	87.6	234	88.0	22	12.4	32	12.0
Brewer's waste	86	48.3	128	48.1	92	51.7	138	51.9
Scavenging free range feed	57	32.0	31	11.7	121	68.0	235	88.3
Sourcing water								
Borehole	24	13.5	36	13.5	154	86.5	230	86.5
Health management								
Deworming	128	71.9	188	70.7	50	28.1	78	29.3

Source: Researcher, 2024

In terms of sanitation, 86.5% of HH had toilets, but 27.0% had visible human faecal matter, and 3.4% reported open defecation. Only 77.5% of HH had a clear path to the toilet. These data provide a snapshot of household practices relevant to pig health and hygiene in the study area.

Table 6: Household sanitation

HH sanitation variable linked to gastrointestinal parasitic infections	HHs with -ve response				HHs with +ve response			
	No. of HHs		Pigs owned		No. of HHs		Pigs owned	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Owens toilet in the compound	24	13.5	34	12.8	154	86.5	232	87.2
Clear access path to toilet	40	22.5	55	20.7	138	77.5	211	79.3
Presence of human faecal matter in the compound	130	73.0	255	95.9	48	27.0	11	4.1
Open defecation practiced	172	96.6	257	96.6	6	3.4	9	3.4
Pigs freely roaming around			109	41.0			157	59.0

Source: Researcher, 2024

4.2 Identification and Prevalence of Gastrointestinal Parasitic Infections (GPI)

Table 7: Identification of Specific Pig Gastrointestinal Parasites

Parasites	Positive cases		Negative cases		df	χ^2	P-value
	(n)	(%)	(n)	(%)			
<i>Strongyles</i>	180	67.7	86	32.3	1	6.21	0.013*
<i>Strongyloides</i>	25	9.4	241	90.6	1	0.45	0.502
<i>Fasciola</i>	58	21.8	208	78.2	1	4.89	0.027*
<i>Ascaris</i>	13	4.9	253	95.1	1	0.32	0.572
<i>Coccidia</i>	53	19.9	213	80.1	1	1.89	0.169
<i>Schistosoma</i>	23	8.6	243	91.4	1	0.63	0.426

N-number of samples, Prev (+) (%) - proportion of positive cases expressed as a percentage, df-Degrees of Freedom, χ^2 -Chi-Square, P-value, ** - significant

Source: Researcher, 2024

Out of 266 pig faecal samples examined, seven gastrointestinal parasites were identified (Table 8). The most prevalent were Strongyles (n = 180, 67.7%) and Fasciola (n = 58, 21.8%), both showing statistically significant associations with infection status ($P < 0.05$), indicating a high parasitic burden. Other parasites detected included Coccidia (n = 53, 19.9%), Strongyloides (n = 25, 9.4%), Schistosoma (n = 23, 8.6%), and Ascaris (n = 13, 4.9%), none of which showed significant associations with infection status ($P > 0.05$).

Table 8: Prevalence by Infection Type

Infection type	Positive cases		Negative cases		χ^2	P-value
	(n)	Pre (+) (%)	(n)	%		
Overall infection	197	74.1	69	25.9	0.7425	.066
Single infection	97	36.5	69	25.9	4.73	.054
Multiple infection	100	37.6			3.50	.072

df-degrees of freedom, X^2 - chi-square value, p = p-value, N = frequency of occurrences.

Source: Researcher, 2024

Analysis of fecal samples revealed an overall prevalence of gastrointestinal parasitic infections (GPI) in pigs of 74.1% (n = 197/266), with no statistically significant difference between positive and negative cases ($\chi^2 = 0.74$, $P > 0.05$), suggesting a widespread infection burden. Among the 197 positive samples, 100 (50.8%) had multiple infections and 97 (49.2%) had single infections, with no significant difference between these groups ($P > 0.05$), as shown in Table 9.

Table 9: Prevalence by sub-county

Sub-counties	Total	Negative		Positive		df	χ^2	P-value
	(n)	(n)	(%)	(n)	(%)			
Paloga	46	9	3.4	37	13.9	1	0.67	0.014**
Lamwo TC	45	9	3.4	36	13.5	1	0.52	0.471
Palabek Ogili	45	11	4.1	34	12.8	1	0.41	0.522
Agoro	43	11	4.1	32	12.0	1	0.35	0.553
Padibe TC	38	7	2.6	31	11.7	1	0.85	0.356
Palabek Kal TC	49	22	8.3	27	10.2	1	1.23	0.028**
Total	266	69	25.9	197	74.1			

df-degrees of freedom, X^2 - chi-square value, p = p-value, N = frequency of occurrences.

Source: Researcher, 2024

The prevalence of gastrointestinal parasitic infections (GPI) varied across the six sub-counties in Lamwo District. Paloga had the highest prevalence at 13.9% (n = 37), followed by Lamwo TC at 13.5% (n = 36), while Palabek Kal TC recorded the lowest at 10.2% (n = 27). Negative cases ranged from 2.6% in Padibe TC to 8.3% in Palabek Kal TC. Statistically significant prevalence was observed in Paloga ($\chi^2 = 0.67$, $P = 0.014$) and Palabek Kal TC ($\chi^2 = 1.23$, $P = 0.028$), indicating a higher parasite burden in these sub-counties as summarized in table 10.

4.3 Risk Factors Associated with Pig Gastrointestinal Parasitic Infections (GPI)

As summarized in Table 10, correlation analysis revealed a moderate positive association between demographic factors (e.g., household size, education level, occupation, and latrine use) and the occurrence of gastrointestinal parasitic infections in pigs ($r = 0.602$, $P = 0.005$). This indicates that household characteristics significantly influence the risk of GPI.

In addition, a statistically significant moderate correlation was observed between pig management practices (such as deworming practices, housing systems, feeding practices, and watering source) ($r = 0.525$, $P = 0.000$). These findings suggest that poor husbandry practices contribute meaningfully to the spread and persistence of gastrointestinal parasites among pigs.

Both associations were statistically significant at the $P < 0.01$ level, underscoring the importance of improving pig management systems and addressing demographic vulnerabilities at the household level to reduce GPI prevalence.

Table 10: Pearson Correlation Between Demographic Factors, Pig Management Practices, and Gastrointestinal Parasitic Infections (GPI) in Pigs

Correlations		
Variable		Gastrointestinal parasitic infections
Demographic factors	Pearson Correlation	.602**
	Sig. (2-tailed)	.005
	(n)	178
Pig management	Pearson Correlation	.525**
	Sig. (2-tailed)	.000
	(n)	178

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

Source: Researcher, 2024

Multivariate logistic regression was performed to identify independent risk factors associated with gastrointestinal parasitic infections in pigs. The results, summarized in Table 12, indicate that several demographic and management-related variables were not significantly associated with GPI prevalence. These include farmer's gender, education level, and age ($P > 0.05$), as well as pig-level variables such as sex, age, and housing system (full confinement vs. mixed).

However, pig breed emerged as a significant predictor of GPI. Compared to local breeds, exotic pigs had lower odds of infection (AOR = 0.31, $P = 0.018$), and crossbreeds showed even stronger protection (AOR = 0.02, $P = 0.045$). Among management practices, feeding raw swill was associated with a significantly increased risk of infection (AOR = 3.37, $P = 0.014$). Surprisingly, the presence of human feces in the environment was linked to slightly lower odds

of infection (AOR = 0.87, P = 0.027), though this may reflect reporting bias or unmeasured confounding.

In terms of water sources, pigs with access to piped water had a significantly reduced risk of infection (AOR = 0.07, P = 0.030), as did those with mixed water sources (AOR = 0.20, P = 0.004), compared to pigs relying solely on borehole water.

Table 11: Multivariable Logistic Regression of Risk Factors Associated with Gastrointestinal Parasitic Infections (GPI) in pigs

Variable	Levels	AOR (95% CI)	P-value
Gender	Male =1	1 (ref)	
	Female =2	0.04(0.34998-0.102)	0.921
Education level	1=Primary school or below,	1 (ref)	
	2=Secondary school or equivalent	0.89 (0.45-1.74)	0.728
	3=Higher education	1.46 (0.23-9.34)	0.686
Age	Interception (less than 18 years)	1(ref)	
	18 years or more	0.03(0.013- 0.220)	0.826
Herd size	1 less than 4 pigs	1 (ref)	
	4 pigs or more	0.3840(0.3498-1.098)	0.027*
Pig Sex	1=Male pig	1(ref)	
	2=Female pig	0.5004(0.3277-1.527)	0.127
Pig Age	1=Less than 7 months	1 (ref)	
	2=7 months or older	0.5064(0.3339-1.516)	0.129
Pig breed	1=Local breed	1 (ref)	
	2=Exotic breed	0.30764(0.718-0.428)	0.018*
	3=Cross breed	0.02375(0.415-0.057)	0.045*
Pig housing	1=Any Free Range,	1 (ref)	
	2=Always confined	0.1257(0.5152-0.244)	0.807
Partial confinement and free range	1=Any Free Range,	1 (ref)	
	2=Always confined	0.04597(0.525-0.088)	0.930
Use commercial feed	0=No,	0(ref)	
	1=Yes	0.1888(0.3495-0.540)	0.589
Use only commercial feed	0=No	0(ref)	
	1=yes	0.590(0.5594 -1.053)	0.292
Use fodder	0=no	0(ref)	
	1=yes	0.04(0.41-0.10)	0.920
Use swill	0=no	0(ref)	
	1=yes	0.08888(0.498-0.178)	0.859
Use boiled swill	0=no	0(ref)	
	1=yes	0.2420(0.483-0.500)	0.617
Use raw swill	0=no	0(ref)	
	1=yes	3.3742(1.365-2.471)	0.014
Use brewer's waste	0=no	0(ref)	
	1=yes	0.5237(0.3669-1.427)	0.153
Depend on free-range feed	0=no	0(ref)	
	1=yes	0.7403(0.3879-1.909)	0.056
Different water sources	1 borehole	1(ref)	
	2 piped	0.07371(0.839-0.088)	0.030*
	3 mixed	0.20013(0.375-0.533)	0.004**

Uses borehole water	0=no	0(ref)	
	1=yes	0.4570(0.4731-0.966)	0.334
Deworms pigs	0=no	0(ref)	
	1=yes	0.2629(0.3742-0.702)	0.482
Practice open defecation	0=no	0(ref)	
	1=yes	0.04353(0.928-0.047)	0.963
Has toilet in compound	0=no	0(ref)	
	1=yes	0.3265(0.4922 -0.663)	0.507
Human faeces around compound	0=no	0(ref)	
	1=yes	0.8705(0.7912-1.100)	0.027
Clear path to toilet	0=no	0(ref)	
	1=yes	0.4564(0.4421-1.032)	0.302
Pigs roaming around	0=no	0(ref)	
	1=yes	0.2201(0.3663-0.601)	0.548

CI - Confidence Interval, ref – Reference, P-value - Probability value, AOR – Adjusted Odds Ratio

Source: Researcher, 2024

Table 12: Multivariable Logistic Regression of Environmental Factors Associated with Pig Gastrointestinal Parasitic Infections (GPI)

Variable	Odds ratio (95% CI)	P-value
Altitude	2.478 (2.202-1.125)	0.260
Distance to riparian areas	0.03209 (0.29515-0.109)	0.013
Land area household covered on settlement	0.41263 (0.13729-3.005)	0.026
Average rainfall	3.409 (3.733, -0.913)	0.361

Source: Researcher, 2024

A multivariable logistic regression was conducted to assess the impact of environmental factors on the prevalence of gastrointestinal parasitic infections in pigs. The analysis showed that altitude (OR = 2.48, $p = 0.260$) and average rainfall (OR = 3.41, $p = 0.361$) were not significantly associated with infection risk.

In contrast, proximity to riparian areas was significantly associated with reduced odds of infection (OR = 0.03, 95% CI: 0.30–0.11, $p = 0.013$), suggesting that pigs living near these water bodies may experience lower parasite exposure or benefit from environmental factors limiting transmission.

Additionally, the land area occupied by the household was significantly associated with infection risk, with larger land areas linked to decreased odds of GPI (OR = 0.41, $p = 0.026$). This finding indicates that land use patterns and available space for pig rearing may influence parasite transmission dynamics.

Chapter Five: Discussion

5.1 Prevalence and Predominant Gastrointestinal Parasites in Pigs in Lamwo District

This study established a high overall prevalence of gastrointestinal parasitic infections (GPI) in pigs (74.1%) in Lamwo District, indicating endemicity and widespread transmission under prevailing husbandry systems. This prevalence aligns with previous findings in Uganda by Roesel et al. (2017) and Nissen et al. (2011), which attributed high infection rates to low-input smallholder systems with limited veterinary services and poor sanitation. The high prevalence observed (74.1%) reflects a serious animal health and productivity problem, confirming that gastrointestinal parasites remain among the most significant disease constraints in smallholder pig systems in Northern Uganda. The problem's magnitude mirrors that reported in other endemic districts such as Lira and Masaka (Roesel et al., 2017; Ouma et al., 2022), where infection levels exceeding 70% have been recorded.

Strongyles were the most prevalent parasites, likely due to their soil-transmitted life cycles, which are well-suited to the free-range, soil-exposing environments common in Lamwo. These findings are consistent with Mekuria & Moges (2020) in Ethiopia and Thanasuwan et al. (2024) in Thailand. Contributing factors include exposure to feces, shared water points, and unclean environments. Similarly, Yadav et al. (2018) found that the lack of organized deworming and poor hygiene facilitated the persistence of Strongyle infections.

Ascaris, the second most prevalent parasite, is known for its environmentally resistant eggs that persist in soil for extended periods. Its prevalence is likely driven by open defecation, free-range scavenging, and limited fecal management. Comparable prevalence was reported in Lira, Uganda (Ouma et al., 2022), and Kenya (Githigia et al., 2005). In contrast, Ajayi et al. (2021) in Nigeria found *Ascaris suum* more dominant than Strongyles in semi-intensive systems, suggesting that management systems influence parasite patterns.

Fasciola, although detected at lower levels, reflect localized environmental exposures. These parasites require snail intermediate hosts, commonly found in wet, marshy areas accessed by scavenging pigs. Similar patterns were reported in Zambia (Phiri et al., 2019), Tanzania (Mwakupuja et al., 2021), and Kenya (Maingi & Njoroge, 2010), while low prevalence in well-managed farms (Mukaratirwa et al., 2018) underscores the role of water access control.

Coccidia infections were also documented and are commonly linked to overcrowding, poor hygiene, and inadequate piglet management. Similar findings were reported in Ghana (Aning et al., 2020), Uganda (Tumwine et al., 2020), and Brazil (Silva et al., 2019), where suboptimal sanitation was associated with high Coccidia burdens.

Mixed infections were common, with 36.5% of infected pigs having single infections and 37.6% showing co-infections. These rates suggest continuous exposure to infective parasite stages due to overlapping risk factors. Ndyomugenyi et al. (2021) in Uganda and Habimana et al. (2020) in Rwanda reported similar co-infection dynamics. Strongyle-Ascaris co-infections exacerbate health impacts and complicate treatment, as noted in Kenya and Tanzania (Obonyo et al., 2020; Mwabonimana et al., 2019).

Spatial variation in GPI prevalence across the six sub-counties, notably in Paloga and Palabek Kal, highlights the influence of localized risk factors such as sanitation infrastructure, veterinary access, and land use. Similar spatial differences in parasite burden have been documented in Uganda (Roesel et al., 2017), Cameroon (Ngueguim et al., 2018), and Tanzania (Michael et al., 2020). The observed higher infection rates in Paloga and Palabek Kal are likely due to variations in environmental conditions and management systems. These sub-counties are characterized by more extensive free-ranging, seasonal flooding, limited veterinary outreach, and poorer sanitation infrastructure compared to others. Similar spatial heterogeneity has been attributed to ecological and management differences in Uganda and across East Africa (Roesel et al., 2017; Michael et al., 2020).

5.2 Risk Factors Associated with Gastrointestinal Parasitic Infections (GPI) in Pigs

The study examined demographic, environmental, and management-related risk factors, including pig breed type, rearing system, water source, feed hygiene, and sanitation practices. These variables were selected based on known epidemiological links reported in previous East African studies (Kungu *et al.*, 2019; Ndyomugenyi *et al.*, 2021). The management systems considered included free-range, tethered, semi-intensive, and confined systems, while pig breeds were classified as local, crossbred, and exotic to capture diversity in genetic and husbandry practices that may influence GPI exposure.

5.2.1 Farmer Demographic Characteristics

Pig ownership and sampling varied by sub-county. Palabek Kal had the highest number of sampled pigs (27.5%) and pig-owning households (16.9%), while Agoro Sub-County had the lowest (14.0% and 10.1%, respectively). Variations in infrastructure, market integration, and veterinary service access likely explain these differences (Roesel *et al.*, 2017; Lekule & Kyvsgaard, 2003).

Of the 178 surveyed households, 60.7% were male-headed and 52.2% were household heads. Youth participation was notable, with 56.7% under 40 years of age. However, 59.0% had

attained only primary education or less. This limited literacy may hinder the adoption of scientific husbandry practices (Arvidsson, 2023). Nonetheless, Neset *et al.* (2018) suggest that participatory, visual-based training can overcome literacy-related challenges.

5.2.2 Pig-Level (Host) Factors

Among 266 pigs, 63.9% were female and 52.3% were younger than seven months, indicating ongoing herd replacement. Local breeds were most common (73.7%), followed by crossbreeds (20.3%) and exotic breeds (6.0%).

Multivariable logistic regression showed that breed significantly influenced infection risk. Exotic (AOR = 0.31, $p = 0.018$) and crossbred pigs (AOR = 0.02, $p = 0.045$) had significantly lower odds of infection than local breeds, consistent with findings by Roesel *et al.* (2016). Crossbreeding, when combined with good management, offers potential for improved resistance and productivity (Muhanguzi *et al.*, 2012).

Although pig age and sex were not significant in regression analysis, literature indicates that young pigs have weaker immunity (Nansen & Roepstorff, 1999), suggesting a need for age-targeted control measures. The results confirm that both pig breed and management practices jointly influence infection risk. Local breeds under free-range systems faced the highest exposure due to scavenging behavior and poor confinement, while crossbred or exotic pigs under better-managed systems experienced reduced infection levels. This interaction between genetics and management highlights the importance of integrated control strategies combining improved husbandry with selective breeding.

5.2.3 Pig Husbandry Practices

Housing and Rearing Systems

Free-range scavenging was practiced by 88.8% of households. Pigs were exposed to contaminated environments, including feces, mixed-age cohorts, and stagnant water. Pig shelters were rare, often poorly built, and lacked proper drainage and sanitation. Age groups were not segregated. These findings are consistent with Obonyi & Njoga (2020), Nansen & Roepstorff (1999), and Kochanowski *et al.* (2017), who highlighted the link between housing, hygiene, and parasite transmission.

Feeding and Watering Practices

Only 8.4% of households exclusively used commercial feeds. Most relied on fodder and crop residues (73.6%), and 51.7% supplemented with brewer's waste. Feeding raw swill

significantly increased infection risk (AOR = 3.37, $p = 0.014$), likely due to contamination with infective parasite stages. Water was mainly obtained from boreholes (86.5%), but pigs drinking piped water (AOR = 0.07, $p = 0.030$) or mixed sources (AOR = 0.20, $p = 0.004$) were less likely to be infected. These results are aligned with previous reports by Phiri *et al.* (2003) and Obonyo *et al.* (2013). The findings suggest that both water quality and source are significant risk factors for GPI. Pigs drinking from open or stagnant sources such as ponds, ditches, or unprotected wells are at a higher risk due to contamination with parasite eggs or larvae, whereas clean, treated, or piped water reduces exposure potential.

Health and Biosecurity Practices

Only 28.1% of households dewormed pigs, and most lacked proper dosing or veterinary guidance. Quarantine measures were absent, and waste disposal was poor. These gaps facilitate chronic infections and increase resistance risk, consistent with findings by Abonyi & Njoga (2020).

5.2.4 Environmental Factors

Location and Landscape Effects

Households near riparian areas had lower infection odds (OR = 0.03, $p = 0.013$), and larger land area also reduced infection risk (OR = 0.41, $p = 0.026$). Altitude and rainfall were not significantly associated. Similar environmental influences were reported by Nganga *et al.* (2008) and Esrony *et al.* (1997). The observed variation in infection prevalence across sub-counties may be attributed to differences in pig husbandry practices, sanitation coverage, and ecological conditions. For example, Paloga and Palabek Kal Sub-counties had more low-lying and poorly drained areas, greater reliance on free-ranging, and limited veterinary outreach, all of which favor the persistence and transmission of parasite eggs.

Sanitation Conditions

Despite 86.5% of households having latrines, visible feces were present in 27.0% of compounds, and 3.4% practiced open defecation. Unexpectedly, visible feces were associated with slightly lower infection odds (AOR = 0.87, $p = 0.027$), possibly due to observer bias or unmeasured confounding. Effective sanitation requires correct and consistent usage, not just infrastructure (Roesel, 2018; Wanyama & Leitner, 2019). Morphological identification through coprological examination was used because it remains a cost-effective and reliable diagnostic method for field-based epidemiological surveys in rural contexts. While molecular techniques

may offer greater sensitivity, morphology-based methods provide sufficient accuracy for determining prevalence patterns and dominant parasite taxa in resource-limited settings.

Although this study was conducted in Lamwo District, the identified risk factors poor sanitation, free-range management, and limited veterinary access are typical of smallholder pig production systems across Northern Uganda. Therefore, the findings can inform control interventions in other districts with similar environmental and production characteristics.

5.2.5 Statistical Analysis of Risk Factors for GPI

Statistical analysis identified several significant factors associated with the prevalence of GPI in pigs. Pearson correlation analysis demonstrated a moderate positive association between household demographic variables such as age, gender, education level, and sanitation status and GPI prevalence ($r = 0.602$, $p = 0.005$). Similarly, pig management practices were significantly correlated with infection occurrence ($r = 0.525$, $p < 0.001$). These findings underscore the combined effect of both social and technical factors in shaping infection risk, consistent with studies by Akinmoladun *et al.* (2016) and Ngwili *et al.* (2020).

However, multivariable logistic regression analysis indicated that farmer-level demographic factors specifically age, gender, and education were not independently associated with GPI prevalence. Instead, management and environmental factors exhibited stronger statistical associations. Among host-related factors, pig genotype emerged as a significant predictor: exotic breeds (AOR = 0.31, $p = 0.018$) and crossbreeds (AOR = 0.02, $p = 0.045$) had significantly lower odds of infection compared to local breeds. These findings reinforce earlier reports by Roesel *et al.* (2016) that link breed type and susceptibility under extensive systems.

Feeding practices also influenced infection risk. Feeding raw swill was associated with a significantly higher likelihood of GPI (AOR = 3.37, $p = 0.014$), possibly due to contamination with infective parasite stages. Regarding water sources, pigs provided with piped water (AOR = 0.07, $p = 0.030$) or mixed sources (AOR = 0.20, $p = 0.004$) had a lower risk of infection compared to those relying solely on borehole water likely reflecting microbial contamination or poor water hygiene. These findings are consistent with those reported by Phiri *et al.* (2003) and Obonyo *et al.* (2013).

An unexpected observation was that the presence of visible human fecal matter around homesteads was associated with a slightly reduced infection risk (AOR = 0.87, $p = 0.027$). This counterintuitive result may be due to confounding, misclassification, or observer bias, and warrants further investigation.

Environmental factors also played a role. Households located near riparian areas and those with larger land holdings had significantly lower infection odds (OR = 0.03, $p = 0.013$ and OR = 0.41, $p = 0.026$, respectively). In contrast, altitude and rainfall were not significantly associated with GPI in this study, aligning with previous findings by Nganga *et al.* (2008) and Esrony *et al.* (1997).

Collectively, these results highlight the complex and multifactorial nature of GPI transmission, reinforcing the need for integrated control strategies that prioritize improved feeding practices, water hygiene, breed selection, and environmental sanitation

5.3 Conclusion

This study confirms a high prevalence of GPI in pigs in Lamwo District, with Strongyles emerging as the most dominant parasite, followed by Ascaris, Fasciola, and Coccidia. Infection rates showed significant spatial variation, with Paloga and Lamwo Town Council registering the highest prevalence, underscoring the role of local environmental and management conditions.

Key risk factors associated with higher GPI prevalence included traditional free-range rearing systems, feeding of raw swill, proximity to riparian areas, poor sanitation particularly the exposure of pigs to human fecal matter and the predominance of local pig breeds. Additionally, pigs in smaller herds and less confined systems were more exposed to infection than those in larger or enclosed herds.

GPI transmission in smallholder pig production is shaped by a complex interplay of demographic, husbandry, and environmental factors. Effective control strategies must therefore be comprehensive, focusing on improvements in feed and water hygiene, sanitation, housing, genetic selection, and access to veterinary services. Crucially, regular deworming programs and farmer education are essential to reducing the parasitic burden and enhancing pig productivity in the region.

5.4 Recommendations

To Pig Farmers

For better prevention and control of GPIs in the region, it is recommended that farmers in high-risk areas adopt an integrated approach combining best husbandry practices, use of resilient pig genotypes, and improved health care. Specifically, this should include:

1. Improving feed hygiene, especially by boiling swill before feeding to reduce transmission of infective parasite stages.
2. Enhancing animal management through better housing and gradual transition from free-range systems to partial or full confinement.
3. Improving general household sanitation and hygiene to minimize pig exposure to human fecal material.
4. Selecting or crossbreeding with resilient pig genotypes that are less susceptible to gastrointestinal parasites.
5. Enforcing sanitation policies by local authorities, particularly on waste disposal and latrine coverage, to minimize environmental contamination.
6. Conducting routine coprological surveillance to inform appropriate parasite control measures, considering the correlation between environmental factors and GPI prevalence.

To Veterinary and Agricultural Extension Services

Strengthen farmer sensitization and extension programs focusing on parasite control, improved housing, and safe feeding practices.

Promote community-based deworming campaigns and affordable access to anthelmintics.

To Researchers

Further studies are needed to:

Evaluate the distribution and diversity of GPIs in the wider Northern Uganda region.

Investigate the transmission dynamics of these parasites in different management systems.

Assess the cost-benefit and behavioral feasibility of proposed parasite control strategies among smallholder farmers.

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Appendices

Appendix 1: Household Questionnaire (English Version)

A questionnaire to determine the prevalence, risk factors and develop evidence base Management of porcine gastrointestinal parasite in Lamwo district.

Please note that your answer is absolutely confidential, and your name will not be discussed in any report. Also, your individual answer will not be shared with anyone.

District_____

Subcounty_____

Village_____

HHD ID._____

Age of respondent_____

GPS Coordinates Latitudes.....Longitudes.....

Section A: General information on Socio-demographic characteristics of the study participants.

1. Gender of survey respondent (1=male, 2=female, 3=other)	
2. Total number of pigs kept	
3. Breed of pigs	
4. Estimated age of pigs	

Section B: Farming practices associated with pig gastrointestinal parasite

1. Pig housing. Indicate how pigs are mainly housed / kept. If the farmer does not keep that type of pig (e.g., boars) put -99 for not applicable.

Types of pigs kept	Time period	
	Day	Night
1. Piglets	[] []	[] []
2. Sows	[] []	[] []
3. Boar	[] []	[] []
Main way of housing /keeping pigs (code a)		
1= free range 2= tethered 3= housed, 77=other, specify [_____]		

2. Feeding practices. Complete the following in relation to feeding of the pigs over the last 2 years

Feed-type / source	Feed used in dry season (1=yes, 0=no)	Feed used in wet season (1=yes, 0=no)	Source – list up to the main two (Code a)
Maize bran			[] []
Rice bran			[] []
Commercial concentrate			[] []
Sweet potato vines			[] []
Home mixed rations			[] []
Sweet potato roots			[] []
Cassava leave (raw)			[] []
Cassava leaves (boiled)			[] []
Yam leaves			[] []
Amaranth spp.			[] []
Wandering jew / pig weed			[] []
Kitchen leftovers (boiled swill)			[] []
Kitchen leftovers (unboiled swill)			[] []
Brewery waste			[] []
Commercial feeds			[] []
Spurge			[] []
Banana peels			[] []
Napier grass			[] []
Grazing, specify what on [_____]			[] []
Other, specify [_____]			[] []
Source (code a)			
1 = on own farm 2 = on another farm, used for free 3 = on another farm, paid for 4 = communal - accessed for free 5 = communal - paid for			

6 = purchased from feed supplier / feed shop
 7 = purchased from feed miller
 8 = obtained for free from feed miller
 9 = purchased from brewery
 10 = obtained for free from brewery
 11 = purchased from restaurant / hotel / school / hospital
 12 = obtained for free from restaurant / hotel / school / hospital
 77 = other, specify below [_____]

3. Pig watering

Water source	Source in rainy season (1= yes, 0 = no)	Source in dry season (1= yes, 0 = no)
Q1. Piped Water into The House		
Q2 Piped Water to Yard/Plot		
Q3. Public Tap/Standpipe		
Q4. Private Borehole/Well		
Q5. Public Borehole/Well		
Q6. Natural Spring		
Q7. Lake		
Q8. Dam or Pond		
Q9. Rainwater Collection		
Q10. Other (Specify)		

4. Routine treatment, prevention and control against pig gastrointestinal parasite.

Deworming practices	
Q01. How Often Do You Deworm Your Pigs? (Code A)	
0 Never	
2 After every 2 months	
2 3 months interval	
3 Once a month	
4 3-month interval	
5 = When advised by the vet doctor/buyer (e.g., in the case of contract farming)	
77 = other _____	

Q02.When Did You Last De-Worm Your Pigs (<i>Code B</i>) 1= in the last week 2= in the last one month 3= in the last 3 months 4 = more than 3 months 5 = I can't remember 77=other	
Q03.Which Deworming Drug Did You Use the Last Time? (<i>Code C</i>) (<i>Ask to see the bottle and put down the active ingredient name</i>) 1= Albendazole 2= Levamisole 3= ivermectin 4= Piperazine 77= other _____	

THANK YOU

Appendix 2: Lapeny pi Ot Acel Acel (Acholi version)

Section A Lok ma kwako kom.

1 In Itye Anga

Dako [] Laco []

2 Wel Opego Adii Ma Igwoko?

3 Kit Opego Meni Ma Itye Kwede?

4 Mwaka Pa Opego Ni Twero Bedo Adii?

Section B Farming Practices Associated with Pig Gastro Intestinal Parasites.

Kit Opego Ango Ma Ki Gwoko	Cawane	
	Dyeceng	Dyewor
1. Lutino Opego	[] []	[] []
2. Megi Opego	[] []	[] []
3. Opego Malacoo	[] []	[] []

Yoo Kit Ma Ki Gwoko Ki Opegi

1 Kibwoto Gi Woto Awoto

2 Ki Tweyo Gi Atweya

3 Bedi I Ot

4 Mukene

Kit Ma Gi Bedo Ka Pito Ki Opegi Inge Aryo Angec

Kit Cam Ma Ki Pito Ko Opego	Cam Ma Ki Tiyo Kwede I Kare Me Oroo (1=Ayee, 0 Pe Aye)	Cam Ma Ki Tiyo Kwede I Kare Me Cwii (1=Ayee, 0 Pe Aye)
1. Nge Anywegi Ma Ki Wanyo		
2. Nge Mucele Ma Ki Wanyo		
3. Commercial Concentrate		
4. Pot Layatta		
5. Cam Ma Gang Ma Gi Rubu Gi		
6. Pot Gwana Ma Pe Ki Tedo		
7. Pot Gwana Ma Ki Tedo		
8. Pot Obato		
9. Malakwang		
10. Lototo		
11. Dek Ma Odong Ki lot Tedo Ma Nongo Ki Lyeto		
12. Dek Ma Odong Ki I Ot Tedo Ma Pe Ki Lyeto		
13. Cet Kongo		
14. Commercial Feeds		
15. Spurge		
16. Nge Labolo Ma Ki Wanyo		

Kama Ki Romo Nongo Cam Ket (A)

1 I Oporto Ma Megi

2 I Oporto Mukene Ma Itiyo Kwede Me Nono

3 I Oporto Mukene Ma I Culu Pire

4 I Oporto Pa Lwak Ma Tiyo Kwede Me Nono

5 I Oporto Pa Lwak Ma I Culu Pire

6 I Wilo Cam Ki Bot Ngat Ma Cato Cam

7 I Wilo Cam Ki I Cuma Ma Reko Cam Ni

8 Kede I Nongo Cam Me Nono Ki I Cuma Ma Reko Cam

9 I Wilo Cam Ki Kama Ki Yubu Kongo

10 I Nongo Me Nono Ki Kama Ki Yubu Kongo

11 I Wilo Cam Bene Ki Ka I Ot Cato Cam, Hotel, Gang Kwan Onyo Ot Yat

12 Kede I Nongo Me Nono Ki Ot Cato Cam, Hotel , Gang Kwan Onyo Ot Yat

13 Mukene I Twero Waco Ne

Kit Pii Makitiyo Kede Bot Opego	Pii Makitiyo Kede I Kare Me Cwii (1=Kitiyo Kede, 0=Pe Ki Tiyo Kede)	Pii Makitiyo Kede I Kare Oroo (1= Kitiyo Kede, 0=Pe Kitiyo Kede)
1. Pii Matiyo Ki Pipe Matye I Ot		
2. Pii Matiyo Ki Pipe Matye I Ngom		
3. Tap Pa Lwak		
4. Tangi Ma Megi Onyo Pii Ma Mol		
5. Tangi Ma Lwak Onyo Pii Ma Mol		
6. Pii Oraa Ma Mol		
7. Nam Ma Dit		
8. Pii Ma Ki Gengo Tenge		
9. Pii Kot Ma Ki Jolo		
10. Mukene Tye Itwero Waca		

4 Yat Ma Ki Miyo Kere Ki Kere, Gwoko Ki Gengo Ki Kom Two Kwidi Ma Mako Opego

Pe Kare Maromani Ma Imiyo Yat Kwidi Bot Opegi Ni

1 Pe Amiyo Matwal

2 Amiyo I Nge Dwe Angwen

3 I Nge Adek

4 Ki Cel

5 Ka Dactar Lee Omiya Tam Onyo Lawil Totwale Bot Lupur Mamako Contract

6 Awene Ma I Giko Miyo Yat Kwidi Bot Opego?

1 I Cabit Ma Agiki

2 I Nge Dwe Acel Angec

3 I Nge Dwe Adek Ma Okato

4 Kato Dwe Adek

5 Wiya Pe Poo

6 Mukene

7 Yat Kwidi Mene Ma Itiyo Kwede Me Agiki

1 Albendazole

2 Levamisole

3 Ivermectin

4 Piperazine

5 Mukene

Apwoyo Matek

Appendix 3: Activity plan/Time line

Proposal title: Prevalence and Major Risk Factors Associated with Selected Gastrointestinal Parasites Among Pigs in Lamwo District, Uganda

Duration of project: 6 months

Expected sample size: 360 pigs and 180 pig farmers

Activity	Timeline	Resource	Responsible person
Stakeholder consultation on research topic and proposal	July ,2024	Facilitations	Avudraga stanely
proposal development	August ,2024	stationaries	Avudraga stanely, supervisors
Research proposal presentations	August ,2024	Travels and accommodation	Avudraga stanely
Field visits /data collection	Sept ,2024	Data collection tool and transport means	Avudraga stanely, ILRI team
Laboratory sample analysis	Oct ,2024	Regents and equipment	Avudraga stanely
Data entry and mgt	November ,2024	Laptop and bundle	Avudraga stanely
Data analysis	November, 2024	Laptop and bundle	Avudraga stanely
Report writing	December ,2024	Stationaries	Avudraga stanely, Supervisors
Presentation and dissemination of results	December,2024	Stationaries	Avudraga stanely
Submission of final report	December ,2024	Stationaries	Avudraga stanely

Appendix 4: Informed Consent Document (English Version)

Title of the study: Prevalence and Major Risk Factors Associated with Selected Gastrointestinal Parasites Among Pigs in Lamwo District, Uganda

Investigator(s): Avudraga Stanely, David Waiswa and Ngwili Nicholas.

Institution(s): Gulu University, Faculty of Agriculture and Environment and International Livestock Research Institute.

Introduction

I am Avudraga Stanely, a student for Master of Science in animal production and marketing at Gulu University and currently employed by Lamwo District Local Government as District Veterinary Officer. You are being requested to participate in a research study.

This study is a requirement for the award of the Degree of Master of Animal Production and Marketing of Gulu University.

A brief description of the sponsors of the research project

The study is part of a larger research project being conducted by the International Livestock Research Institute on controlling zoonotic *Taenia Solium* infection in Agago, Lamwo, Pader and Kitgum districts of Northern Uganda.

Specifically, the study aimed at obtaining information on issues related to the infection or presence of porcine gastrointestinal parasites in Lamwo District.

Purpose:

The study will provide epidemiological information on porcine gastrointestinal parasites by determining the prevalence, major risk factors and their correlation for some porcine gastrointestinal parasite's infections in Lamwo district. This will guide the design and implementation of control measures to prevent gastrointestinal parasitic disease in pigs and reduce the zoonotic risk associated with gastrointestinal parasites of pigs to humans.

More so it will help boost the piggy sector in terms of health and welfare of the pigs and increase farmer's income since costs /losses like treatment and mortalities will be reduced.

Procedures:

Your participation in this study will involve asking you a few questions regarding on demographic characteristics (Gender, age, number of pigs and breed), pig production and management practices (Types of pigs kept, Ways of housing or keeping pigs, pig feeding, pig watering), treatment, prevention and control of pig gastrointestinal parasites (deworming

practices, frequency of deworming, last time deworming was done, which drug was used for deworming).

Who will participate in the study?

You have been randomly chosen to participate in this study from among the many pig farmers in your village with the help of the LC 1.

The interview will last for approximately 10-20 minutes.

There is no foreseeable risk of harm or discomfort that will arise from your participation in this study. The only risk or discomfort will be the inconvenience in terms of time spent during the interview.

Benefits:

The Participants will get feedback on findings and progress of the study, any new information that affects the study participants (including incidental findings) will be made available to research participants.

Confidentiality:

Your identity will not be revealed to any one by using codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be protected by password and hard copy files will be kept under lock and key.

Alternatives:

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.

Cost:

The research respondents will be given a bar of soap in appreciation for their time.

Questions:

If you have any questions related to the study, or your rights as a research participant, you can contact the principal investigator, Avudraga Stanely on telephone number +256782488565 or via email on savudraga@gmail.com or the following researchers Nicholas Ngwili- +254710294613, or Mr. David Waiswa, - +256 772481812

Statement of voluntariness:

Participation in the research study is voluntary and you may join on your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any questions concerning the study? Or any clarification you wish to know pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee, Dr. Julaina A. Obika Tel: No., 0772964491; email:

j.obika@gu.ac.ug; or the Uganda National Council for Science and Technology, on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500

Statement of consent

The details of this study have been described to me, what is going to be done, the risks, the benefits involved and my rights as a participant in this study. I understand that my decision to participate in this study will not affect me in any way. In the use of this information, my identity will be concealed. I am aware that I may withdraw at any time. I understand that by signing this form, I do not waive any of my legal rights but merely indicate that I have been informed about the research study in which I am voluntarily agreeing to participate. A copy of this form will be provided to me.

Name

Signature/thumbprint of participant.....Date

Name.....

Signature of witness.....Date.....

Name.....

Signature of interviewer..... Date.....

Appendix 5: Informed Consent Document (Acholi Version)

Wilok madit me kwed: KIT MA KWIDI MAMAKO OPEGO BEDO KEDE I LAMWO DICTRIK

Lukwed: Avudraga Stanely, David Waiswa and Ngwili Nicholas.

Dul: Gulu University, Faculty of Agriculture and Environment and International Livestock Research Institute

Nyute

An nyinga Avudraga Stanely, latin kwan me rwom kwan ma malo me “Gwoko ki cato lee” (Master of Science in animal production and marketing” me Gulu University. Ikom kare ni, atye ka tic macalo dakta ma dit pa lee ii lamwo dictrik. Atye ka legi me bedo lagam lok ikwed man.

Kwed man tye gin acel ma mite pi tyeko kwan mamega me digiri me rwom mamalo ii Gulu university ikom gwoko ki cato lee (Degree of Master of Animal Production and Marketing of Gulu University).

Ngec macek ma tito lumii lim me kwed man

Kwed man obedo but kwed madit ma dul ma loyo timo kwed ikom lee iwilobo ni tye katimo ne

pi miti me kati ki yoo me gengo nya pa kwidi owak mayelo opego ii Agago, Lamwo, Pader ki Kitgum dictrik ikumalo me Uganda.

Atikane, miti pa kwed man tye me nongo lok malube ki tye pa kwidi ma mako dok yelo cin opego dok kelo lanyut calo cado, ki jonyo pa opego ii lamwo dictrik.

Miti pa kwed man

Kwed eni obi miyo lok onyo ngec madok ikom kwidi owak niwok ki ikom rwom me dwong pa kwidi ni, jami ma nyayo kwidi ni, ki rwom me two ma patpat makwidi man kobo ikom opego ii Lamwo dictrik. Man obi tiro yoo mamero ki kwany me aketa itic pi gengo kwidi opego ki juku two ma mako dano ki ikom opego.

Maloyo weng, obikonyo me dongo pur opego malube ki yotkom kacel ki berbedo pa opego ki medo kero me lim pa lupur opego pien acara me imiyo yat, ki too pa opego bedo nok.

Yoo me peny

Abipenyi lapeny ma nok (mengeyo ka in lacoo onyo dako, mwaka ni, wel opego ma igwoko, ki kodi opego ma itye ka gwoko ne), diro me gwoko opego, (dul pa opego, ot opego, cam pa opego, pii bot opego), yoo me cango ki gengo kwidi opego (yat, tyen adii ma imiyo yat bot opego, awene ma imiyo yat me agiki, yat ango ma imiyo me agiki ki opego).

Anga ma bigamo lapeny?

Kiyero in atura me bedo ikwed man ki kony pa won kom acel (LC1) pien in itye ikin lupur magwoko opego i caro mamegwu kany. Nywako tam man obi tero dakika maromo 15 me oo ii 20. Pe tye peko onyo ret mo ma bibino malube ki bedo pa in ikwed man.

Magoba bot lutedero

Gin kubinongo adwogi pa kwed man ki lok ducu manyen magudu komgi malube ki gwoko opego.

Gwoko mung

Kibigwoko lok mamegi ducu imung, nyingi pe wabi coyo ento wabitiyo ki alama. Lok ma wacoyo ki boti bibedo bene imung bot an kena macalo lakwed man.

Yeyo mamegi

Ka ipeke ki miti me gamo lapeny mamega, pe adiyi, dok pe tye gin mo ma in ibirwenyo.

Acara me gamo lapeny

Abimiyo cabun bar acel acel bot jo ducu ma gubedo ikwed man.

Lapeny mamegi

Ka itye ki lapeny madok ikom kwed man, onyo twero ni macalo lagam peny, itwero goyo cim bot ladit maloyo kwed man (Avudraga Stanely) I nama cim +256782488565 onyo icoo lapeny mamegi ki ii email bot savudraga@gmail.com onyoo lukwed magi: Nicholas Ngwili- inama cim +254710294613, onyoo Mr. David Waiswa, inama cim - +256 772481812.

Mok mamegi labongo dic

Dic mop eke ikomi wek ibed ikin lugam lapeny me kwed man. Itwero donyo ka gamo lapeny man imiti ni. Itye bene ki twero me giko gamo lapeny man icawa mo keken labono pwod mo kibota.

Ka itye ki lok/ lapeny malube ki twero mamegi pi bedo ikwed man, itwero goyo cim bot wonkom ma loyo lok kom kwed me Gulu University, Dr. Julaina A. Obika Tel: No., 0772964491; email: j.obika@gu.ac.ug; or the Uganda National Council me Science ki Technology, nonge plot 6 Kimera Road, Ntinda, Kampala tye Tel 0414705500

Lok ma moko yee mamega

Kitito bota lok matut madok ikom kwed man, gin ma obitime icawa me kwed man, peko matwero bino, magoba ma abinongo, kacel ki twero mamega me bedo ikwed man. Aniang ni

yeyo na me bedo ikwed man pe obi kelo peko mo ikoma. Ikare me tic ki lok ma awaco, nyinga pe bi kati woko. Atye ki ngec ni atwero juku mede ki gamo lapeny man icawa mo keken. Aniang ni keo cinga I form man pe nyutu twero mamega malube ki cik mo keken ento ni kinianga ki lok mamako kom kwed eni ma atye ki yeyo iye labongo dic. Ki bi miya karatac me yeyo man dong bota.

Nying lagam lapeny Cing lagam lapeny.....Nino dwe.....

Nying lapeny peny.....Cing lapeny peny..... Nino dwe.....

Nying lapeny peny.....Cing lapeny peny..... Nino dwe.....

Appendix 6: Community Engagement Plan

STUDY TITLE: Prevalence and Major Risk Factors Associated with Selected Gastrointestinal Parasites Among Pigs in Lamwo District, Uganda

Principle Investigator: Avudraga Stanely

Rationale of the study

The study provides epidemiological information on porcine gastrointestinal parasites in Lamwo District. This will guide the design and implementation of control measures to prevent gastrointestinal parasitic disease in pigs and reduce the zoonotic risk associated with gastrointestinal parasites of pigs. This will also help boost the piggery sector in terms of the health and welfare of the pigs and increase farmer's income since costs /loses like treatment and mortalities will be reduced.

General objective and specific objectives to be achieved

General objective

To determine the prevalence, major risk factors and their correlation for some porcine gastrointestinal parasite's infections in Lamwo district, Uganda.

Specific Objectives

- I. To identify the most predominant GIT parasites among pigs in Lamwo District.
- II. To determine prevalence of selected GIT parasites among pigs in Lamwo District
- III. To determine major risk factors associated with prevalence of selected pigs GIT parasites in Lamwo district

The objectives of the community engagement are to.

- I. Sensitize the community and stakeholders about the research and gather real-time feedback.
- II. Clarify the roles and responsibilities of stakeholders involved in the study before, during, and after its implementation.
- III. Address key ethical concerns by explaining the benefits of the study, ensuring the community understands the value of the research, and detailing the consent process and participants' rights.

The key community stakeholders

I will involve the following stakeholders:

Smallholder pig farmers

The International Livestock Research Institute (ILRI) team

Lamwo District technical staff

Local Council leaders of selected sub-counties

I will maintain constant engagement of stakeholders throughout the duration of research,

The research team responsible for managing community engagement activities

S/N	Research Team	Technical abilities	Tasks/lead roles
1	Avudraga Stanely	Extension service delivery on Livestock health, production and management	Will lead the research team, coordinate and oversee the implementation of the Community engagement plan
2	Mr. David Waiswa	Lecturer, Animal Production and Range Management	Main supervisor from Faculty of Agriculture and Environment, Gulu University. will respond to questions regarding ethical issues and significance of the research to the community
3	Dr. Nicholas Ngwili	Post-Doctoral, Animal & Human Health research Programs coordination	Supervisor from Internal Livestock Research Institute, will coordinate legal document development and sharing of information to meet community interest
4	Dr.salaviriuse ahimbisibwe	Livestock health Researcher	Field team leader in data collection, analysis and management

Approach and Activities:

Formative Consultations:

I will conduct formative consultations to understand the geographical, socio-cultural, and demographic context of the study areas. These consultations will involve field visits to familiarize ourselves with local practices, power structures, and perceptions. We will also engage with sub-county authorities and veterinary offices to gain insights into governance structures and demographic characteristics.

Community Stakeholders' Partnerships:

To gain community entry, I will seek permission from Lamwo District Chief Administrative Officer (CAO), work with the District Veterinary Officer in gaining community entry and engage existing community structures and stakeholders as follows:

S/N	Stakeholders	Roles/Involvement
1	Chief administrative officer (CAO)	Host Inception meetings at district head quarter
2	District Veterinary Officer (DVO)	Provide Planning and technical consultations
3	Sub-county chiefs	Host Inception meeting at sub-county level
4	Assistant veterinary officers	Mobilization and selection of pig farmers
5	Local Council One	Guide and help formulate list of farmers at village level
6	Pig Farmers	Provide socio-demographic information and participate in faecal sample collection

Community Events:

I will conduct community meetings and outreach activities to educate communities and stakeholders about the study and gather real-time feedback by co-chairing meetings with the sub-county veterinary assistants, private veterinary practitioners, local council leaders, and pig farmers. Discussions will focus on community concerns, demographic characteristics, pig production systems, hygiene practices, and strategies for controlling pig gastrointestinal parasites. I will encourage participants to share their opinions and experiences.

Communication Strategy:

I will maintain continuous communication with stakeholders throughout the study. Before consultative meetings, I will contact local council leaders, assistant veterinary officers, the DVO, DPMO, and the CAO to schedule appointments. During these meetings, I will introduce the subject matter, take notes, and record proceedings for later review. Extracts from these meetings will be used to refine the research approach.

To share research results, I will produce and distribute leaflets during workshops. These will include findings, challenges, lessons learned, and recommendations. `

Risk and Conflict Mitigation:

I will address risks and conflicts as soon as they are detected, with the potential to inform GUREC and UNCST of any adverse developments. Anticipated risks include:

1. Infectious Disease Spread:

I will ensure that the study team adheres to strict prevention measures, including the use of disinfectants and handwashing during sample collection, to prevent the spread of notifiable diseases such as African swine fever.

2. Participant Apathy:

To combat potential apathy due to previous research activities in the area, I will work closely with local leaders to educate the community on the health benefits of the study.

3. Community Misperceptions:

I will share comprehensive information about the study, particularly the zoonotic risks associated with pig gastrointestinal parasites, to prevent misunderstandings and conflicts.

Evaluation Plan:

I will conduct evaluations before, during, and after the research. This will include reviewing field notes, minutes, documents, and observations made during community engagements. Feedback will be carefully analyzed, and any discordant feedback will be addressed to ensure the objectives of the community engagement and the research are met.

Appendix 7: Covid-19 and other Public Health Risk Management Plan 2024

Measures for the Prevention and Control of the Spread of Infectious Diseases During the Implementation of Research

Study Title: Prevalence and Major Risk Factors Associated with Selected Gastrointestinal Parasites Among Pigs in Lamwo District, Uganda

Principal Investigator: Avudraga Stanley

Introduction

Infectious diseases, including but not limited to COVID-19, pose significant risks during research activities. These diseases can be transmitted through various modes, including respiratory droplets, direct contact, or contact with contaminated surfaces. Symptoms may range from mild respiratory issues to severe conditions like pneumonia, organ failure, and death.

I am committed to ensuring the safety of the research team, participants, and the communities involved in the study. I will adhere strictly to the Standard Operating Procedures (SOPs) issued by the Ministry of Health and other relevant authorities to mitigate the risk of spreading infectious diseases.

Implementation of Prevention and Control Measures

In my role as the Principal Investigator, I will take proactive steps to enforce and monitor the following procedures throughout the research process:

A. Prior to Data Collection and Training

1. **Health Guidance:** I will lead sensitization and awareness sessions to educate the research team and participants on recognizing symptoms of infectious diseases and understanding preventive measures. I will emphasize hand hygiene, proper mask usage, and maintaining social distancing.
2. **Wearing Face Coverings:** I will ensure that all individuals involved in research activities, including myself, wear face masks that fully cover the mouth and nose as per the Health Ministry's guidance. If anyone lacks a mask, I will provide one.
3. **Physical Distancing:** During training, meetings, and community outreach, I will enforce reasonable social distancing measures.

4. **Good Hygiene Practices:** I will ensure that all team members regularly wash their hands or use hand sanitizers. I will make sure handwashing equipment is available at all times and that surfaces and equipment are frequently sanitized.

B. During Data Collection

1. **Personal Protective Equipment (PPE):** I will ensure that all research assistants and participants use properly fitted face masks during in-person interviews and other interactions. I will personally ensure hand hygiene before and after each interview and prohibit handshakes and hugging.
2. **Consent Process:** I will oversee the consent process, ensuring that social distancing is observed and that both researchers and participants sanitize their hands before the interview. I will also ensure that participants are informed about preventive measures against infectious diseases.
3. **Equipment Sanitization:** I will ensure that all devices used for data collection, such as tape recorders, are sanitized regularly.

C. During Dissemination/Community Engagement

1. **Community Engagement:** I will ensure that all participants in community engagement activities wear masks, wash their hands, or use hand sanitizer before the event begins.
2. **Equipment Sanitization:** I will make sure that all shared devices used during community engagements are sanitized regularly.

Appendix 8: Faecal sedimentation S.O.P

Step 1.

Add about 2-5g of faeces to 200mls of water and sieve through a tea strainer in a clean 250mls beaker.

Step 2.

Add 2 drops of liquid detergent (liquid soap) to the homogenate to improve the release of eggs from faecal material.

Step 3.

Allow the mixture to settle for 10-20 minutes and then pour off the supernatant.

Step 4.

If the supernatant is not clear, add more water to the sediment and leave to settle for about 10-20 minutes.

Repeat step (III) until the supernatant is clear enough.

Step 5.

Pour off the clear supernatant and transfer the sediment in a petri dish. Place the petri dish under the microscope and read under x10 objective lens.

Central Diagnostic Laboratory CoVAB Makerere University

Compiled by Avudraga Stanely

Appendix 9: Modified McMaster S.O.P

The most common and efficient way to obtain fecal egg counts for pigs, sheep, goats, young cattle and horses is to use the Modified McMaster Test. This is a flotation test that separates parasite eggs from debris based on density; the eggs float to the surface of the counting chamber. This test uses a special microscope slide with a grid, which makes counting easier (Figure 1). Manure and flotation fluid is measured and mixed and only a small portion of the total mixture is counted. A calculation is performed to determine the number of eggs/grams in the manure. This technique can be used to count strongylid (also called strongyle or trichostrongyle) eggs, coccidia and

Egg quantification test materials

- I. Scale to weigh fecal sample. Scale must weigh in 0.1-gram increments; a digital kitchen scale could be used.
- II. Two paper or plastic cups, at least 5 ounces
- III. Fecal flotation solution (can be Fecasol®, a commercially available solution, sugar solution, or a saturated solution of pickling salt (NaCl) or Epsom salts (MgSO₄) - see procedure notes on how to make this solution.)
- IV. Dispenser bottle, measuring cup or large syringe for measuring flotation solution
- V. Tongue depressor / craft stick or spoon for mixing
- VI. Straining technique – this can be a tea strainer; unfolded gauze 4” X 4” pads or squares; or cheese cloth cut into squares (6” squares preferred)
- VII. 2-chamber McMaster slides. See procedure notes for more information including suppliers.
- VIII. 1 ml syringe, or eye dropper, or transfer pipette for filling slide
- IX. Compound microscope with internal light source, moveable stage and 4X and 10X objective lenses. A binocular microscope is more comfortable than a monocular scope, but not essential.
- X. Timer

Fecal Collection Supply List:

KY Jelly / lubricant, Container with cooler/ice packs, Refrigerator, McMaster microscope slide, Exam gloves (powder free is best) , Labels (1” x 3”) to identify sample , Permanent marker

Procedure

- I. Using a digital weighing scale, weigh 4g of faecal matter, add 56mls of floatation solution (saturated NaCl solution) to make a final volume of 60mls in a plastic beaker.

Half the volumes in cases of inadequate samples

- II. Gently homogenize (mix), followed by sieving
- III. Using a pasteur pipette, transfer the mixture into the McMaster chamber until it's just full,

Empty the chamber and refill in case of any air bubbles

- IV. Allow the slide to sit, settle for at least 5 minutes to allow the floatation process to occur before examining.
- V. Examine under x10

Appendix 10: Environmental variables used in the analysis of porcine gastrointestinal infections in Lamwo District

Variable	Source	Data type
Landcover	Classification of Sentinel image in QGIS	Raster
Hospitals	https://data.humdata.org/dataset/hotosm_uga_health_facilities	Vector
Rivers	DIVA-GIS (https://diva-gis.org/data.html)	Vector
Normalized difference vegetation index (NDVI)	Generated from Google Earth Engine	Raster
Rainfall	CHIRPS (https://data.chc.ucsb.edu/products/CHIRPS-2.0/)	Raster
Altitude	DIVA-GIS (https://diva-gis.org/data.html)	Raster
Slope	Generated from Altitude data using QGIS	Raster

Appendix 11: Photos

Photos 1&2: showing Sample Collection



1-Pig restrains using pig snare



2-Faecal sample collection from the rectum

Photos 3&4: showing setting of Laboratory



Laboratory Tools, Reagents, Faecal samples and Examination S.O. Ps

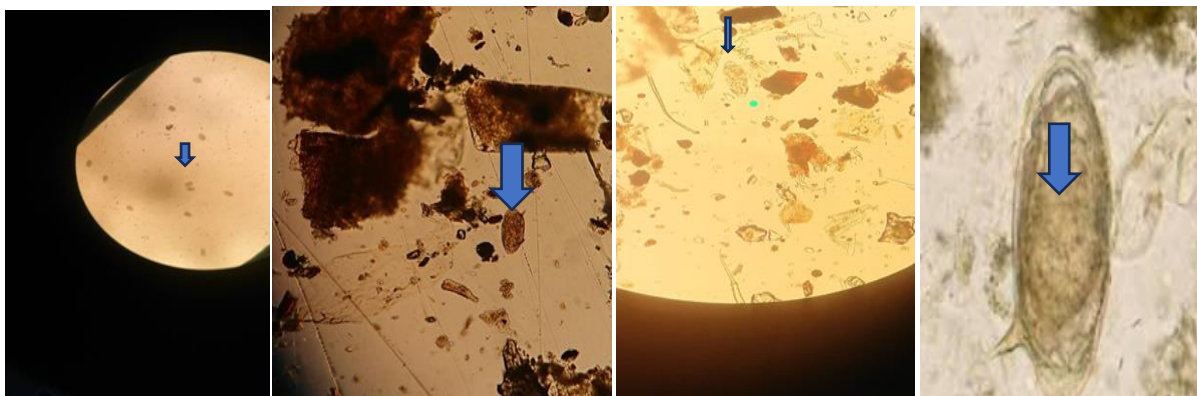
Photos 5,6,7&8: Showing Laboratory Sample preparations



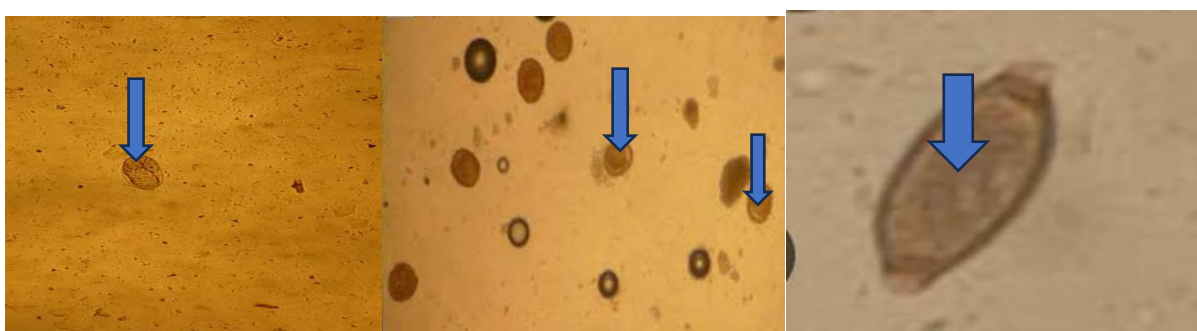
Photo 9: Showing Examination by using microscope



Photos 10, Eggs of Gastrointestinal parasites in pig under 10X / 40X electronic microscope



1- Eggs of mites 2- Egg of Strongyles 3- Eggs of coccidia 4-egg of Schistosoma



4- Eggs of strongyloides 5- Eggs of ascaris 6- Eggs of fasciola

Photo 10: Showing laboratory data records

Sl. No.	Age	Sex	Species	Number of eggs	Number of eggs	Number of eggs
1	344	G	Ascaris	100	-	0.000
2	343	G	Ascaris	100	-	0.000
3	343	M	Strongyloides	100	-	0.000
4	344	M	Ascaris	100	-	0.000
5	345	M	-	-	-	0.000
6	346	M	Ascaris	100	Ascaris	0.000
7	347	M	Ascaris	100	-	0.000
8	348	M	Ascaris	100	Strongyloides	0.000
9	350	F	-	-	-	0.000
10	351	M	Strongyloides	100	-	0.000
11	352	M	Strongyloides	100	-	0.000
12	353	F	Ascaris	400	Strongyloides	0.000
13	354	F	Strongyloides	100	-	0.000
14	355	M	Strongyloides	100	Strongyloides	0.000

Photo 12: showing questionnaire administering and follow up on pig farmers

