PREVALENCE AND MANAGEMENT FACTORS ASSOCIATED WITH GASTRO-INTESTINAL PARASITES OF PIGS AMONG SMALL-SCALE FARMERS

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ABSTRACT
The study determined the prevalence of gastro-intestinal parasites in pigs and their association with management practices in Dodoma urban district, Tanzania. Two hundred and sixteen (216) pigs were selected randomly from the district for faecal sample collection. The faecal samples were analysed in the laboratory through faecal flotation and sedimentation methods. A structured questionnaire was administered to the owners of the pigs to gather information about management practices. The groups of parasites identified and their prevalence were Oesophagostomum spp. (46%), Strongyloides ransomi (44%), Ascaris suum (36%), and Trichuris suis (18%). The odds of a pig being infested with Strongyloides ransomi was higher where the pig pen was cleaned once per week compared to where it was cleaned every day or twice per week. On the other hand, the odds of a pig being infested with Oesophagostomum spp. was lower where pigs were fed processed feed compared to leftovers. The study shows that deworming is an important management practice to control gastro-intestinal parasites in pigs, as the odds of a pig being infested by all parasite species was lower where deworming was practiced. Farmers should be educated on the importance of deworming and hygienic conditions in pig production

Keywords: *Gastrointestinal parasites, management practises, pig, prevalence, and small-scale farmers*

INTRODUCTION

Pig farming is a significant global activity that provides a valuable source of food for humans and raises the economies of many nations (Yu and Jensen, 2022). Pigs are raised in many parts of the world due to their excellent adaptability to a variety of environmental conditions. In addition, their fast growth rate, high fecundity rates, and short generation intervals result in quick cash generation (Enem et al., 2010). Global pig production was estimated at 1.2 billion metric tonnes in 2020, with China being the largest producer (53.9 million metric tonnes) and consumer (FAOSTAT, 2021). Future projections indicate that demand for pork will increase due to rising demand in Asia and Africa (OECD/FAO, 2022; Yu and Jensen, 2022).

Pig production is an important activity in the agricultural industry in Tanzania (Kimbi et al., 2015; Maziku *et al.,* 2017). The industry is dominated by smallholder farmers who keep pigs for both subsistence and commercial purposes

(Kimbi *et al.,* 2015; Michael *et al.,* 2018). The pig population in Tanzania was estimated at more than 3.2 million, and more than 99% are kept by small-scale farmers under traditional production systems (NBS, 2021). Indigenous breeds, which are well adapted to the local environment and production systems, are commonly kept in Tanzania. The pigs are either kept in intensive systems where they are confined or in a free-range production system where they scavenge at backyards and garbage dumping sites searching for food (Kimbi et al., 2015). However, commercial pig production is gaining popularity, particularly in urban areas with limited grazing land for ruminants (Wilson and Swai, 2014).

The demand for pork in Tanzania has increased in urban and peri-urban areas due to changes in customer preferences and population increase (Henjewele, 2015). However, the smallholder production system is vulnerable to diseases and parasites due to poor management practices (Komba et al., 2013). Gastrointestinal parasites are one of the major constraints on the pig industry in most parts of the world (Roepstorff et al., 2011). Parasitic infections of pigs are estimated to be second in importance to African swine fever in tropical areas due to poor management practices and favourable conditions for growth and multiplication (Jufare et al., 2015). The parasitic infestation reduces the performance of pigs and leads to subsequent economic losses (Roepstorff et al., 2011). Common gastrointestinal parasites in pigs in Tanzania are nematodes, helminths, and coccidia (Kabululu et al., 2015; Nonga and Paul, 2015). The scavenging nature of pigs and their consumption of a wide range of feeds increase the risk of swallowing parasite eggs and larvae from the environment (Kaur et al., 2017).

Management practices have a significant impact on parasite transmission and the susceptibility of the pigs to parasitic infestations (Gabriël et al., 2017; Roesel et al., 2017). Infestations of parasites are exacerbated by poor housing and contaminated feed and water. Good sanitation of the pig pen prevents faecal-oral transmission and contamination of food and water (Gabriël et al., 2017). On the other hand, adequate feeding reduces the negative effects of parasites on feed conversion efficiency and average daily weight gain (Lai et al., 2011). Animal factors, such as sex and age, may increase the susceptibility of animals to parasites and thus influence the levels of parasitism (Fourie et al., 2019). Parasitic infestations can be controlled by routine deworming and vaccination, especially in young and growing pigs (Kouam et al., 2018; Fourie et al., 2019).

In a rapidly growing region like Dodoma, pig production is an important economic activity that provides human food and income. However, successful expansion of pig production will depend on an understanding of management practices that influence parasite infestation. Knowledge of parasite control practices is also necessary for developing strategies to reduce the impacts of parasites on livestock. Thus, the current study aimed to determine the prevalence of gastro-intestinal parasites in pigs in the Dodoma urban district and the role of management practices in parasite infestations. The rapid population growth of the region has increased demand for food, especially animal protein. On the other hand, the arid nature of the region reduces the availability of pasture for expanding ruminant production. As a result, pigs can perform well due to their dietary flexibility. However, successful expansion of pig production in the region will depend on knowledge of management practices that influence pig health. Thus, the objectives of the study were to determine the prevalence of gastrointestinal parasites in pigs in Dodoma urban district; and to determine the associations between the prevalence of gastrointestinal parasites and the management practices of the pigs.

MATERIAL AND METHODS

Study area

The Dodoma region falls within the semi-arid central zone of Tanzania. The region receives an average rainfall of about 447 millimetres per year, falling during the wet season between De-

cember and April (Ngongolo and Kilonzo, 2022). The average temperature is 25°C, with a minimum of 18°C and a maximum of 32°C (Ngongolo and Kilonzo, 2022). The region is growing rapidly due to the shift of government headquarters from Dar es Salaam to the region and the establishment of the University of Dodoma. The population of the region has increased from 2,083,588 in 2012 to 3,085,625 in 2022 (URT, 2022). Dodoma urban district is the capital city of the region and the most urbanised district.

Crop production is the main economic activity in the Dodoma region, while livestock production is the second major economic activity. The main livestock species are cattle, goats, and chickens (NBS, 2021). Pigs are the least important livestock in the region (NBS, 2021). However, due to the rapid growth of the population, pig production is likely to be a profitable venture in the region due to the availability of pork consumers. In addition, the increase in urbanisation is expected to reduce grazing land for ruminants, especially in the Dodoma urban district. However, Dodoma is among the regions with high infections of gastrointestinal parasites in pigs (Mkupasi et al., 2011), so identifying factors causing the infections is necessary for the successful expansion of pig production.

Study design and sample size determination

A cross-sectional survey was conducted to assess the prevalence of gastrointestinal parasites in pigs in the Dodoma urban District from February to June 2022. Four wards were purposefully selected from the Dodoma urban districts based on the availability of pig farmers. The wards were Chang'ombe, Msalato, Kikuyu, and Majengo. The sample size of the study pigs was established based on the formula developed by Thrusfield (2018). The formula is given as:

$$N = \frac{1.96^2 \times P_{exp}\left(1 - P_{exp}\right)}{d^2}$$

where,

P_{exp} = expected prevalence

d = desired absolute precision

N = the total sample size. Based on the study of gastrointestinal parasites in pigs by (Nonga and Paul, 2015) in Arusha, we expected a prevalence of 83%. Based on a 95% confidence interval (CI) and 5% absolute precision, the sample size for the study was 216 pigs.

Data collection

Sample size of the pigs from each ward was determined based on the total number of pigs in each ward. Random sampling was used to obtain farmers and the required number of pigs from each ward. Faecal samples were collected in the morning from 8:00 a.m. to 10:00 a.m. The samples were collected directly from the rectum of the study animals by a veterinary officer. Clean disposable gloves were worn on each pig, and a finger was carefully inserted into the rectum of the pig to collect faeces. The samples were immediately placed in plastic zip-lock bags and stored in a cool box. The samples were then brought to the laboratory at the College of Natural and Mathematical Sciences of the University of Dodoma on the same day for analysis. The samples were observed directly for the presence of blood or adult worms. Qualitative analysis of the faecal samples was done using the procedures described by Hansen Perry (1994). The faecal flotation and sedimentation procedure was followed to separate parasite eggs or oocysts from the faecal material. The parasite eggs, or oocysts, were collected using glass slides and examined under a microscope. The identification of the gastrointestinal parasites was done based on the morphological features of the eggs (Figure 1). A structured questionnaire was used to gather information about the management of the pigs, which includes deworming, housing, cleanliness, and feeding practises by the farmers. The study adhered to informed consent from all the participants and confidentiality. An ethical approval for conducting the study with reference number MA.84/261/02 was offered by the University of Dodoma.

(A) **(B)** **(C)**

Figure 1: Morphological features of parasitic eggs identified from the faecal samples collected: (A) *Ascaris suum* (B) *Oesophagostomum* spp. (C) and *Strongyloides ransomi*

Data analysis

The samples were classified as positive when at least one parasite egg was found. Descriptive statistics such as percentages were determined in Microsoft Excel. The prevalence of different parasites was determined by dividing the number of positive samples by the total number of samples evaluated. The positive and negative parasitic tests were converted into binary outcomes, where the positive test was denoted by 1 and the negative by 0, for logistic regression analysis. A multivariate logistic regression analysis was performed in R version 4.3 to obtain the odds ratios (OR) and 95% confidence intervals of the factors associated with parasitic infections in the pigs. These factors were the sex of the pig, type of feed used (commercial or leftovers), the frequency of cleaning the pig pen per week (once, twice, or every day), and deworming practises (yes or no). A p-value threshold of < 0.05 was used to determine statistical significance.

RESULTS AND DISCUSSION

The overall prevalence of gastrointestinal parasites was 80%. The main parasites identified and their prevalence were *Oesophagostomum spp.* (46%), *Strongyloides ransomi* (44%), *Ascaris suum* (36%), and *Trichuris suis* (18%). Worm infestation is one of the challenges facing the expansion of pig production in Tanzania (Wilson and Swai, 2014). The prevalence and species of the parasites identified support previous studies in Tanzania (Esrony *et al*., 1997; Nonga and Paul, 2015) and other East African countries (Roesel *et al*., 2017; Tumusiime *et al*., 2020). Our findings show that the majority of the pigs were affected by multiple species of gastrointestinal parasites. Forty-seven percent of the pigs that tested positive were infected by more than one parasite species. *Oesophagostomum* spp. had the highest frequency, followed by *Strongyloides ransomi* and *Ascaris suum*. *Oesophagostomum* spp. are prevalent in the world, particularly when pigs are raised in traditional systems due to contamination of feed and water (Lai *et al*., 2011; Li *et al*., 2017). Previous studies in Tanzania (Esrony et al., 1997) and Kenya (Nganga et al., 2008) have reported similar prevalence and species of the parasites. In addition, a study by Maganga *et al*. (2019) in Gabon also found that *Oesophagostomum* spp. was the most common, with a prevalence of 50%. *Strongyloides ransomi* and *Ascaris suum* are common gastrointestinal parasites in many parts of the world in tropical and sub-tropical climates due to favourable environmental conditions (Roesel *et al*., 2017; Tumusiime *et al*., 2020; Adhikari *et al*., 2021). However, variation in the prevalence among different studies could be attributed to sex, breeds of pigs, climate, sampling season, and different management practices.

Deworming and sanitation measures were the main factors that influenced the likelihood of infestation for all parasite species (Table 1). The odds of a pig being infested with *Strongyloides ransomi* was lower where deworming was practiced compared to where it was not practised ($p = 0.011$) and 13 times higher where the pig house was cleaned once per week compared to where it was cleaned every day or twice per week (Table 1, Figure 2). On the other hand, the odds of a pig being infested by *Oesophagostomum spp.* was lower where deworming was practised and higher where pigs were fed kitchen leftovers (Table 1, Figure 3). Furthermore, the odds of a pig being infected by *Ascaris suum and multiple parasites was lower where deworming was practiced* (Table 1, Figure 4). This study shows the importance of deworming in pig production for preventing gastrointestinal parasites. The use of dewormers is necessary, especially for small-scale farmers where hygienic and biosecurity measures are less taken (Jufare et al., 2015; Roesel *et al*., 2017; Pettersson *et al*., 2021). Routine deworming eliminates parasites, reducing economic losses and human health risks. The results agreed with previous studies that found lower parasitic infections in dewormed pigs compared to non-dewormed pigs (Fourie *et al.,* 2019; Abonyi and Njoga, 2020; Sharma et al., 2020). However, more than half of the farmers in this study did not practice deworming, probably due to a lack of awareness of the importance of deworming. Farmers may also avoid the costs of buying dewormers, but the losses due to poor growth may be higher than the costs of deworming. Co-infection with different intestinal parasite species is common in pigs (Ngwili *et al.,* 2022). Thus, effective control of parasites in pigs is achieved through a combination of anti-parasitic drugs and hygienic measures (Roesel et al., 2017; Pettersson *et al*., 2021).

The intensive system of pig production was practiced by all the farmers visited, where pigs were confined in an enclosure. However, the majority of the pig pens were not cleaned regularly, particularly due to the limited water supply. About 53% of the farmers cleaned the pig pens once per week. The prevalence of *Strongyloides ransomi* was higher in farms where pig pens were cleaned once per week compared to those cleaned twice per week or every day. Under favourable conditions, *Stongyloides ransomi* eggs hatch within a few hours after passing out of the host to form larvae (Viney and Lok, 2015). Thus, frequent removal of manure is important to reduce contamination of feed and water. In addition, the coprophagy behaviour of pigs increases the chances of ingesting parasite eggs in dirty pens (Steenhard et al., 2000; Sharma et al., 2020). This behaviour can further enhance the infection of pigs with these parasites. Frequent cleaning can eliminate parasite eggs from the surroundings, whereas pen disinfection can kill the parasites and eggs (Pettersson et al., 2021).

The majority of the farmers (76%) used processed pig feed bought from feed shops, while 24% depended on agricultural and kitchen leftovers. Feeding pigs kitchen leftovers is a common practice in small-scale pig production in Africa (Obonyo et al., 2013; Dadas et al., 2016; Roesel et al., 2017; Weka, 2020). However, the likelihood of a pig being infected by *Oesophagostomum* spp. and *Strongyloides ransomi* was higher among farmers who used leftovers as pig feed compared to those who used processed feed. Although processed feeds may carry parasites and pathogens (Mramba, 2023), leftovers have a higher risk of carrying parasites due to poor handling and dirty utensils and environments where they are collected (Mekonnen et al., 2014). However, a related study by Obonyo et al. (2013) did not find a contribution of leftovers to the transmission of intestinal parasites, indicating that when properly handled, leftovers can offer an alternative source of pig feed in small-scale pig production.

CONCLUSION

Pigs raised by small-scale farmers in Dodoma district have a high prevalence (80%) of intestinal parasites. The study also shows that some management practices can significantly reduce the prevalence of intestinal parasites in pigs.

Table 1: Parameter estimates for the likelihood of a pig being infested by *Strongyloides ransomi, Oesophagostomum* spp., *Ascaris suum*, and multiple parasite species infestations with respect to different parameters

Variable	Category	OR	SE	*z*	*p*	95% CI for the OR
The likelihood of a pig being infected by *Strongyloides ransomi*						
Intercept		0.3	0.1	-2.06	0.038	0.1-0.7
Pig sex	male	1.2	0.4	0.32	0.744	0.5-2.9
Deworming	yes	0.3	0.1	-2.54	0.011	0.1-0.7
Feed type	kitchen leftovers	0.6	0.3	1.71	0.086	0.9 -11
Cleaning frequency	once/week	13.0	0.9	2.71	0.006	2.5 -18.7
	twice/week	3.4	0.9	1.33	0.182	1.6 -16.2
The likelihood of a pig being infected with *Oesophagostomum* spp.						
Intercept		1.1	0.7	2.57	0.211	0.7- 3.5
Pig sex	male	0.6	0.4	-0.98	0.326	0.3- 1.5
Deworming	yes	0.3	0.1	-3.05	0.002	0.1- 0.5
Feed type	kitchen leftovers	0.4	0.2	2.61	0.008	0.1- 0.6
Cleaning frequency	once/week	0.5	0.3	1.02	0.303	1.1- 1.9
	twice/week	1.2	0.7	0.83	0.403	0.5- 7.6
The likelihood of a pig being infected by *Ascaris suum*						
Intercept		1.6	0.4	1.65	0.216	0.4-6.8
Pig sex	male	0.9	0.4	-0.09	0.920	0.4-2.4
Deworming	yes	0.3	0.1	-2.94	0.003	0.1-0.5
Feed type	kitchen leftovers	0.9	0.5	-0.04	0.966	0.3-2.9
Cleaning frequency	once/week	0.5	0.3	-0.97	0.327	0.1-2.0
	twice/week	0.6	0.2	-0.73	0.465	1.1-2.4
The likelihood of a pig being infected by multiple species of parasites						
Intercept		0.94	0.1	-1.07	0.294	0.2-4.3
Pig sex	male	0.5	0.2	-1.44	0.149	0.2-1.3
Deworming	yes	0.2	0.5	-3.93	< 0.001	0.1-0.3
Feed type	kitchen leftovers	1.5	0.6	0.71	0.478	0.4-5.4
Cleaning frequency	once/week	3.3	0.7	1.55	0.121	0.7-7.3
	twice/week	1.7	0.7	0.74	0.456	0.3-8.9

OR = odds ratio, SE = standard error, CI = confidence interval, z = z-scores, p = is the level of marginal significance within a statistical hypothesis test.

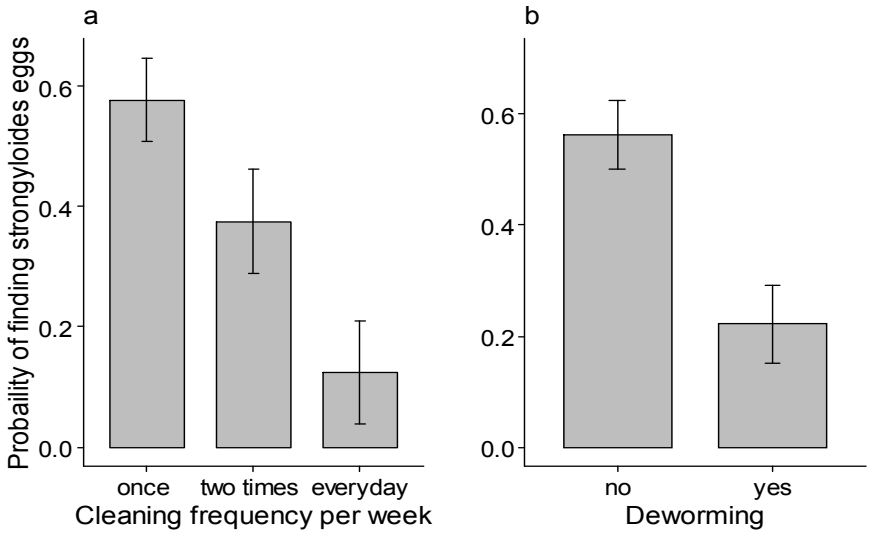

Figure 2: Association between the probability of finding *Strogyloides ransomi* eggs in the faecal samples and (a) the cleaning frequency of the pig pens (b) deworming practises

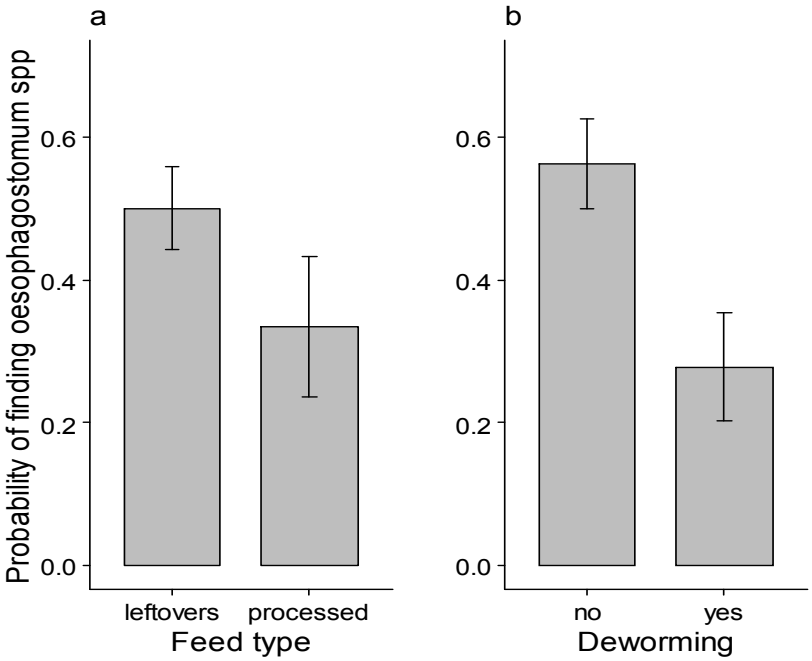

Figure 3: Association between the probability of finding *Oesophagostomum* spp. eggs in the faecal samples and (a) feed type (b) deworming practises.

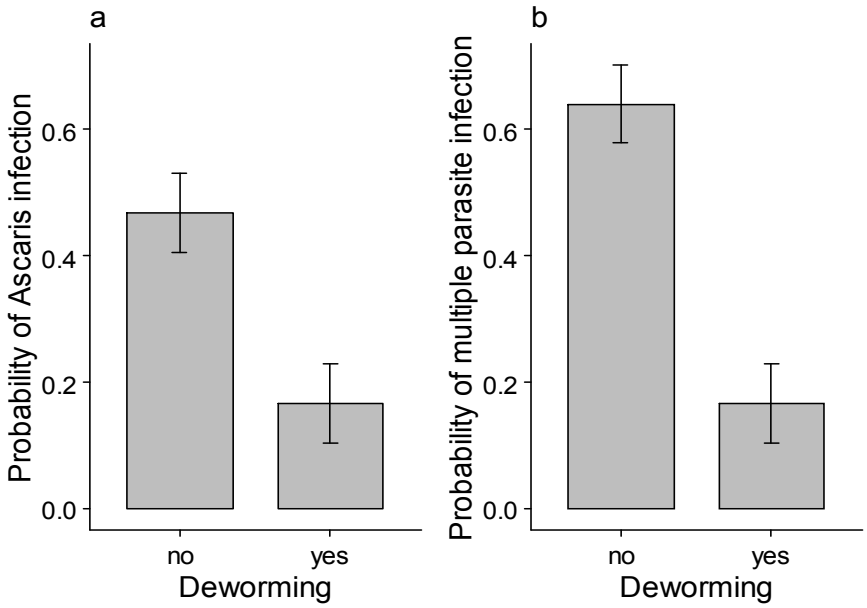

Figure 4: The influence of deworming practises on the likelihood of: (a) *Ascaris suum* infections and (b) multiple parasite infections in pigs.

Deworming is an important management practice for controlling the infestation of gastrointestinal parasites in pigs. Another important management practice is good sanitation. However, the majority of the farmers did not practice deworming or proper hygiene. This might be due to a lack of knowledge and awareness of the importance of these management practices. Because pigs are scavengers and eat a variety of food materials, farmers may not be aware of the importance of keeping their environment clean. This study recommends the provision of education on the importance of deworming and hygiene practices in pig production to reduce gastrointestinal parasite infestation.

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DECLARATIONS
The authors declare that there are no financial or personal interests to disclose.

REFERENCES
Abonyi, F.O. and Njoga, E.O. (2020). Prevalence and determinants of gastrointestinal parasite infection in intensively managed pigs in Nsukka agricultural zone, Southeast, Nigeria. Journal of Parasitic Diseases, 44: 31-39.

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

Dadas, S., Mishra, S., Jawalagatti, V., Gupta, S., Vinay, T. and Gudewar, J. (2016). Prevalence of gastrointestinal parasites in pigs (Sus scrofa) of Mumbai region. International Journal of Science, Environment and Technology, 5: 822-826.

Enem, S., Owoleke, D. and Suleiman, A. (2010). Improved Pig Production and Performance in the Tropics. Animal Production Research Advances, 6.

Esrony, K., Kambarage, D., Mtambo, M., Muhairwa, A. and Kusiluka, L. (1997). Helminthosis in local and cross-bred pigs in the Morogoro region of Tanzania. Preventive Veterinary Medicine, 32: 41-46.

FAOSTAT. (2021). Food and Agricultural Organisation, Agricultural Data . FAO, Rome (Crops and livestock products domain availableat ttps://www.fao.org/ faostat/en/# QCL [Accessed 02 June 2023]).

Fourie, P., Roberts, H. and Nwafor, I.C. (2019). Prevalence of gastrointestinal helminths and parasites in smallholder pigs reared in the central Free State Province. Onderstepoort Journal of Veterinary Research, 86: 1-8.

Gabriël, S., Dorny, P., Mwape, K., Trevisan, C., Braae, U., Magnussen, P., Thys, S., Bulaya, C., Phiri, I. and Sikasunge, C. (2017). Control of Taenia solium taeniasis/cysticercosis: The best way forward for sub-Saharan Africa? Acta tropica, 165: 252-260.

Hansen, J. and Perry, B.D. 1994. *The epidemiology, diagnosis and control of helminth parasites of ruminants. A handbook*. International Laboratory for Research on Animal Diseases, Nairobi.

Henjewele, C.J. (2015). Health risks and biosecurity measures in pig production in Urban and Peri-Urban areas of Morogoro Municipality, Tanzania. Sokoine University of Agriculture.

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

Kabululu, M.L., Ngowi, H.A., Kimera, S.I., Lekule, F.P., Kimbi, E.C. and Johansen, M.V. (2015). Risk factors for prevalence of pig parasitoses in Mbeya Region, Tanzania. Veterinary Parasitology, 212: 460-464.

Kaur, M., Singh, B.B., Sharma, R. and Gill, J.P.S. (2017). Prevalence of gastro intestinal parasites in pigs in Punjab, India. Journal of Parasitic diseases, 41: 483-486.

Kimbi, E., Lekule, F., Mlangwa, J., Mejer, H.a. and Thamsborg. (2015). Smallholder pigs production systems in Tanzania. Journal of Agricultural Science and Technology, 5: 47-60.

Komba, E.V., Kimbi, E.C., Ngowi, H.A., Kimera, S.I., Mlangwa, J.E., Lekule, F.P., Sikasunge, C.S., Willingham III, A.L., Johansen, M.V.a. and Thamsborg, S.M. (2013). Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. Veterinary parasitology, 194: 284-291.

Kouam, M.K., Ngueguim, F.D. and Kantzoura, V. (2018). Internal parasites of pigs and worm control practices in Bamboutos, Western Highlands of Cameroon. Journal of parasitology research, 2018.

Lai, M., Zhou, R., Huang, H. and Hu, S. (2011). Prevalence and risk factors associated with intestinal parasites in pigs in Chongqing, China. Research in Veterinary Science, 91: e121-e124.

Li, K., Lan, Y., Luo, H., Shahzad, M., Zhang, H., Wang, L., Zhang, L., Liu, D., Liu, X. and Hao, Y. (2017). Prevalence of three Oesophagostomum spp. from Tibetan Pigs analyzed by Genetic Markers of nad1, cox3 and ITS1. Acta parasitologica, 62: 90-96.

Maganga, G.D., Kombila, L.B., Boundenga, L., Kinga, I.C.M., Obame-Nkoghe, J., Tchoffo, H., Gbati, O.B. and Awah-Ndukum, J.

(2019). Diversity and prevalence of gastro-intestinal parasites in farmed pigs in South-east Gabon, Central Africa. Veterinary world, 12: 1888.

Maziku, M., Desta, S.a. and Stapleton, J. (2017). Pork production in the Tanzanian livestock master plan. Tanzania Livestock Master Plan Brief 6: 1-4.

Mekonnen, B., Erko, B. and Legesse, M. (2014). Prevalence of intestinal parasitic infections and related risk factors among street dwellers in Addis Ababa, Ethiopia. J Trop Dis, 2: 1-7.

Michael, S., Mbwambo, N., Mruttu, H., Dotto, M., Ndomba, C., Silva, M.D., Makusaro, F., Nandonde, S., Crispin, J.a. and Shapiro, B.I. (2018). Tanzania Livestock Master Plan (2017/2018–2021/2022). ILRI, Nairobi, Kenya.

Mkupasi, E.M., Ngowi, H.A. and Nonga, H.E. (2011). Prevalence of extra-intestinal porcine helminth infections and assessment of sanitary conditions of pig slaughter slabs in Dar es Salaam city, Tanzania. Tropical animal health and production, 43: 417-423.

Mramba, R.P. (2023). The role of feeds in the transmission of chicken pathogens in Dodoma Urban District, Tanzania. Poultry Science, 102: 102558.

NBS. (2021). National Sample Census of Agriculture 2019/20. National Bureau of Statistics. The United Republic of Tanzania.

Nganga, C., Karanja, D. and Mutune, M. (2008). The prevalence of gastrointestinal helminth infections in pigs in Kenya. Tropical animal health and production, 40: 331-334.

Ngongolo, K. and Kilonzo, M. (2022). Communities' awareness of afforestation and its contribution to the conservation of lizards in Dodoma, Tanzania. Scientific Reports, 12: 22592.

Ngwili, N., Thomas, L., Githigia, S., Muloi, D., Marshall, K., Wahome, R. and Roesel, K. (2022). Co-infection of pigs with Taenia solium cysticercosis and gastrointestinal parasites in Eastern and Western Uganda. Parasitology Research, 121: 177-189.

Nonga, H. and Paul, N. (2015). Prevalence and intensity of gastrointestinal parasites in slaughter pigs at Sanawari slaughter slab in Arusha, Tanzania. Livestock Research for Rural Development, 27.

Obonyo, F., Maingi, N., Githigia, S. and Ng'ang'a, C. (2013). Farming practices and risk factors for transmission of helminths of free range pigs in Homabay District, Kenya.

OECD/FAO. (2022). Meat consumption per capita: Continued rise of poultry, pig meat and fall of beef. OECD-FAO Agricultural Outlook 2022-2031. OECD Publishing, Paris, France.

Pettersson, E., Sjölund, M., Wallgren, T., Lind, E.O., Höglund, J. and Wallgren, P. (2021). Management practices related to the control of gastrointestinal parasites on Swedish pig farms. Porcine Health Management, 7: 1-12.

Roepstorff, A., Mejer, H., Nejsum, P. and Thamsborg, S.M. (2011). Helminth parasites in pigs: new challenges in pig production and current research highlights. Veterinary parasitology, 180: 72-81.

Roesel, K., Dohoo, I., Baumann, M., Dione, M., Grace, D. and Clausen, P.-H. (2017). Prevalence and risk factors for gastrointestinal parasites in small-scale pig enterprises in Central and Eastern Uganda. Parasitology research, 116: 335-345.

Sharma, D., Singh, N., Singh, H. and Rath, S. (2020). Copro-prevalence and risk factor assessment of gastrointestinal parasitism in Indian domestic pigs. Helminthologia, 57: 28.

Steenhard, N., Storey, P., Yelifari, L., Pit, D., Nansen, P. and Polderman, A. (2000). The role of pigs as transport hosts of the human helminths Oesophagostomum bifurcum and

Necator americanus. Acta tropica, 76: 125-130.

Thrusfield, M. 2018. *Veterinary epidemiology*. John Wiley & Sons Ltd, Oxford, UK.

Tumusiime, M., Ntampaka, P., Niragire, F., Sindikubwabo, T. and Habineza, F. (2020). Prevalence of Swine Gastrointestinal Parasites in Nyagatare District, Rwanda. Journal of Parasitology Research, 2020.

URT. (2022). Population and Housing Census. National Bureau of Satistics. The United Republic of Tanzania.

Viney, M.E. and Lok, J.B. (2015). The biology of Strongyloides spp. WormBook, 16: 1-17.

Weka, R. (2020). Helminth parasites of pigs and humans in north central Nigeria, with a particular focus on Taenia solium. University of Bristol.

Wilson, R.T.a. and Swai, E.S. (2014). Pig Production in Tanzania: a Critical Review. Tropicultura, 32: 46-53.

Yu, W. and Jensen, J.D. (2022). Sustainability implications of rising global pork demand. Animal Frontiers, 12: 56-60.