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Animal health beyond the single disease approach – A role for veterinary herd health management in low-income countries?

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ABSTRACT

In order to identify and evaluate health related constraints faced by Ugandan pig farmers, a veterinary herd health management approach (VHHM) was applied in 20 randomly selected pig farms in the Lira district, Uganda. Regular herd visits were conducted between July 2018 and June 2019, using *e.g.* interviews, observations, clinical examinations and laboratory analyzes to gather qualitative and quantitative data on relevant aspects of the production. The pig farmers kept on average 18.6 pigs, including 2.6 sows/year. The production figures varied considerably but were generally poor. The sows produced 1.6 litters/year and 8.2 piglets born alive per litter, the average daily gain was 101 g/day, and the mortality in growers was 9.7%. Four major constraints were identified; poor nutrition, infectious diseases, inferior biosecurity, and poor reproductive management. The quantity and quality of feed was suboptimal. Endo- and ectoparasites were very common, causing diarrhea, bronchitis, pneumonia, skin lesions and pruritus. Post-weaning diarrhea associated with enterotoxigenic *Escherichia coli* was important in the two largest herds, and parvoviral antibodies were found in seven herds, two experiencing problems with mummified fetuses. Biosecurity practices were insufficient and inconsistent, with free-ranging pigs and the use of village boars being the major risks. Reproductive figures were affected by poor estrus detection and service management. Overall, farmers lacked important knowledge on good management practices. In conclusion, the VHHM identified several important constraints that should be addressed in order to increase the productivity of Ugandan pig herds.

1. Introduction

In low-income countries, efforts to improve animal health have traditionally focused on single, major, infectious diseases, *e.g.* brucellosis, African swine fever (ASF) and foot-and-mouth disease (*e.g.* Okoth et al., 2013; Erume et al., 2016; Sulayeman et al., 2018). In contrast, in high-income countries where several of these diseases are controlled, a more holistic approach, *i.e.* veterinary herd health management (VHHM), is used in order to improve animal health, welfare and productivity (Derks et al., 2013; Ramirez and Karriker, 2019). Thus, there is a scope for investigating the feasibility of such a holistic approach also in low-income countries.

In Uganda, a low-income country with an estimated gross domestic product *per capita* of 620 USD (Development Assistance Committee, 2019; The World Bank, 2019), the pig production has increased tenfold since the mid-1980s (FAOSTAT, 2019). Most of these pigs are found in smallholder farms (Ikwap et al., 2014b; Ndyomugyenyi and Kyasimire, 2015), and an aspired increase in productivity is hampered by several

Abbreviations: ADG, average daily gain; ANF, anti-nutritional factor; ASF, African swine fever; BCS, body condition score; EPG, eggs per gram; ETEC, enterotoxigenic *Escherichia coli*; HE, hematoxylin and eosin; OPG, oocysts per gram; OTC, oxytetracycline; PCR, polymerase chain reaction; PPV, porcine parvovirus; P-S, penicillin-streptomycin; SVA, the Swedish National Veterinary Institute; VHHM, veterinary herd health management.

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constraints, including poor animal health (Muhanguzi et al., 2012; Dione et al., 2014) that is closely linked to productivity (Jørgensen, 1992; Friendship and O'Sullivan, 2015; Kruse et al., 2019). However, very little information is available on production figures, and poor record-keeping has previously been identified as a constraint (Muhanguzi et al., 2012). An increasing amount of knowledge on pig pathogens in Uganda have been generated (Ikwap et al., 2014a; Roesel et al., 2017; Dione et al., 2018; Musewa et al., 2018) and while previous studies have provided important information, there is still a gap of knowledge between the pathogens that are present, and their clinical relevance. In addition, some of the problems that are faced by the farmers are not captured by regular clinical or laboratory work and demand a broader approach (Goodwin, 1971).

Veterinary herd health management is a well-established concept based on regular herd visits, taking all aspects of the production, such as anamnesis, production figures and clinical observations, but also *e.g.* the environment, management, feed and biosecurity, into account (Goodwin, 1971; Basinger, 1985; Enting et al., 1998; Ramirez and Karriker, 2019). The goal of any VHHM program is to improve the overall health and prevent disease, and by doing so also increase the profit for the farmer. The aim of this study was thus to identify and generate in-depth knowledge on the health and productivity constraints faced by Ugandan small-scale pig herds, by using a holistic, flexible and longitudinal approach, *i.e* VHHM.

2. Materials and methods

2.1. Ethical considerations

An ethical permission was obtained from the College of Veterinary Medicine, Animal Resources and Biosecurity at Makerere University, Kampala, Uganda (ref SBLS/REC/18/005), and from the Uganda National Council for Science and Technology (ref A591). A written and oral informed consent was obtained from all farmers before the beginning of the study.

2.2. Study area and selection of herds

The study was conducted in the district of Lira in northern Uganda (Fig. 1). A list of 250 pig farmers, in the most pig-dense villages in four sub-counties located close to the town of Lira, was retrieved from the local District Veterinary Office. Of these, 38 matched the inclusion criteria, *i.e.* to have at least one sow and to keep the pigs either confined or tethered. Twenty farmers were chosen by simple random sampling. If a farmer couldn't be reached for the first visit, another, randomly allotted, farmer was included.

The farms had 0–14 sows, and 15 out of 20 farms were classified as "small", having ≤3 sows/year, while five were classified as "large" (Ouma et al., 2018). All pigs were either cross-breeds or exotic, and no herd kept pure indigenous breeds. Most farms were run as family businesses (16/20).

2.3. Study design

The herds were visited once a month from July 2018 to June 2019, alternating between "primary" and "secondary" visits. A visitors' log was constructed and the farmers were instructed to keep records continuously. Previously recovered data was analyzed and if needed, additional questions were included at the next visit. The statistical calculations were done by a Welch's *t*-test, except in the comparison of fecal egg flotation solutions, where a paired *t*-test was used (Excel, Microsoft, Redmond, Washington, USA).

The primary visits were conducted by the first author, a veterinarian, accompanied by either of two extension workers from the local District Veterinary Office, one being a veterinarian and one an assistant veterinary officer with a diploma in animal husbandry. Information on rearing, management, feeding, reproduction, entries/exits, biosecurity, disease, and treatments was gathered. A semi-structured interview was performed, observations were noted, and clinical examinations and sampling were conducted. The cleanliness of the pens was scored as clean (0), medium (1) or dirty (2) referring to 0–25%, 25–50% or >50% of the floor being covered with fecal material, respectively. All pigs present at the small farms, and all adults plus a random sample of piglets and growing pigs (30–80%) on the larger farms, were sized. Targeted

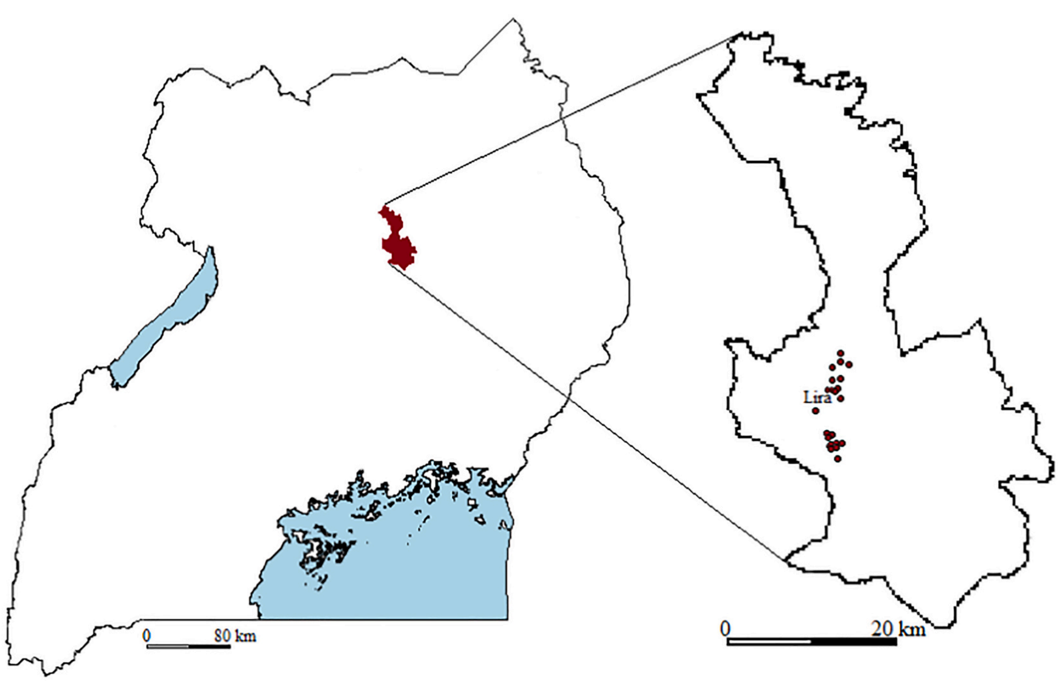

Fig. 1. Map of Uganda with the Lira district highlighted (left). The geographical location of the 20 farms participating in the study is indicated on the map (right). The map was created using files extracted from the Database of Global Administrative Areas, GADM version 3.6.

sampling and screening for ecto- and endoparasites, and for parvoviral antibodies, were performed.

The secondary visits were performed by one of the extension workers. A structured interview was conducted and structured observations were made on reproduction, entries/exits, diseases and treatments. The pigs were sized accordingly.

2.4. Records and production figures

The farmers' records included information on entries and exits, deaths, sickness, treatments, reproduction, and, if appropriate, identity of the pigs. For each category, the records were compared to the information gathered by the interviews, and the compliance was scored as; 0) Not recorded, 1) Major incompliances, 2) Minor incompliances or 3) All events correctly recorded. Minor incompliances were scored if *e.g.* the drug but not the dosage for a treatment was recorded, and major incompliances were scored if *e.g.* some but not all events in a category were recorded, or if unspecific terms like "a pig was treated" were used. After compilation, average scores of <1, 1–2 and >2 were considered as poor, medium and good record keeping, respectively.

The number of sows per year was calculated by the formula;

$$\text{Number of sows}\Big/\text{year} = \frac{\text{The sum of days that sows and gilts after first service were present in the herd}}{\text{The number of days from the first to the last primary visit in the herd}}$$

The piglet mortality was calculated as;

$$\text{Piglet mortality} = \frac{\text{Number of piglets born alive that died before weaning}}{\text{Number of piglets born alive}}$$

The mortality in growers (excluding weaned pigs sold within a week after weaning) and in female adults (including gilts after their first service) were calculated as;

$$\text{Growers}\Big/\text{adult mortality} = \frac{\text{Number of growers/adults that died}}{\text{Number of growers/adults in a herd}}$$

Very sick pigs that were slaughtered were included in the mortality calculations.

For pigs that were weighed more than once, growth rates were calculated as average daily gain (ADG) and combined to herd averages for three categories; 0–3 months, 3–12 months and overall (0–12 months), the latter also including pigs that fell in-between the two other categories.

Animals intended for repeated measurements were either individually ear-tagged or were easily distinguishable otherwise. Pigs $\leq$ 10 kg were weighed by a spring scale ($\leq$12 kg, ref.no. 29940, Albert Kerbl GmbH, Germany), calibrated thrice. The length and heart girth of growing pigs $>$10 kg were measured with a tape, the mean value of two measurements was calculated and the weight was estimated according to Mutua et al. (2011a). In the two largest herds, growing pigs $>$10 kg were weighed with a digital platform scale (ATK5300, HiWEIGH, Shanghai, China). Body Condition Score (BCS; 1–4) of the adults was assessed according to Ramirez and Karriker (2019), the method being slightly adjusted according Kaiser et al. (2020; suppl. material, Table S1).

2.5. Clinical examinations

All pigs in the small, and the breeding stock in the larger farms, were subjected to a thorough clinical examination at the first visit. At the following primary visits, all pigs were inspected and thorough clinical examinations were performed if any animal exhibited signs of disease, or if anamnestic information indicated any health problems.

2.6. Sampling and laboratory investigations

All herds were screened for endoparasites, *Sarcoptes (S.) scabiei* and parvoviral antibodies. Additional investigations such as necropsies and collection of blood-, fecal-, and bacterial samples, were performed if clinically indicated. The pigs subjected to necropsy were euthanized by either blunt trauma to the head followed by exsanguination, or anesthetized by intramuscular injections of xylazine (20 mg/mL, Interchemie werken "De Adelaar" B.V., Venray, Holland) and ketamine (50 mg/mL, Rotexmedica, Trittau, Germany), and euthanized by intracardial injection of KCl (BDH Laboratory Supplies, Poole, England). Tissue specimens were fixed in formalin for 2–4 d, stored in 70% ethanol until being embedded in paraffin, cut in 4-μm sections, stained with hematoxylin and eosin (HE), and examined with light microscopy. Bacterial swabs (eSwab, Copan Diagnostics Inc., Corona, USA) were stored in Amies' transport medium at 4–8 °C and streaked on blood agar plates (Swedish National Veterinary Institute (SVA), Uppsala, Sweden) within two days. Pure cultures of bacteria were transported to SVA for species-identification by matrix-assisted laser desorption ionization time-of-flight mass spectrometry (MALDI-TOF MS, Microflex LT System, Bruker Daltonik GmbH, Bremen, Germany). Antibiotic susceptibility was analyzed by broth microdilution (VetMIC, SVA, Uppsala, Sweden). *Escherichia* (*E.*) *coli* was analyzed by polymerase chain reaction (PCR) for determination of the virulence factors LT and STa in accordance with the EU Reference Laboratory for E. coli (2013), STb in accordance with Frydendahl et al. (2001), and VT2e, modified according to Pass et al. (2000).

PCR-analysis for African swine fever virus on frozen EDTA blood was performed at the Makerere University, Kampala, Uganda. DNA was extracted by the DNeasy® Blood and Tissue Kit (Qiagen, Hilden, Germany) according to the manufacturer's instructions, and amplified by conventional PCR. Briefly, two μL of the sample was added in a 25 μL reaction mixture including primers targeting the viral protein 72- coding region (King et al., 2003). The PCR included an initial denaturation at 95 °C for 20 min, followed by 35 cycles of 95 °C for 15 s, 55 °C for 30 s and 72 °C for 30 s and finally, an extension step of 72 °C at 7 min (Mastercycler® nexus gradient, Eppendorf AG., Hamburg, Germany). The results were visualized by a 2% agarose gel electrophoresis.

2.6.1. Screening for ectoparasites

Pigs were inspected for the presence of lice and fleas. Further, one to two pigs in small, and four to five pigs in larger herds were screened for the presence of *S. scabiei*. Preferably, pigs presenting with clinical signs such as red papules, itch, or hyperkeratotic lesions were sampled. The inner pinna of the ear was scraped with a bone curette (Scoop Single 6 mm, Volkmann) and the scrapings were analyzed according to a protocol modified from Hollanders and Castryck (1989). Briefly, the samples were submerged in 10% potassium hydroxide (SVA, Uppsala, Sweden), incubated at ambient temperature (25–35 °C) for 20–24 h during repeated shaking, the sediment was mixed with ~5 mL of saturated sugar-salt solution (specific gravity 1.27–1.30, SVA, Uppsala, Sweden) and examined by light microscopy (×10, MC20, Micros Austria, St.Veit an der Glan, Austria).

2.6.2. Screening for endoparasites

In each herd, one fecal sample was collected per category: sows in the periparturient period, weaned pigs less than four months of age, and growing pigs >4 months old. Up to three samples per category were pooled to one sample. All samples were analyzed by a simplified McMaster flotation (Monrad et al., 1999). Briefly, 2 g of feces were mixed with 28 mL of a saturated sugar-salt solution (specific gravity 1.27–1.30, SVA, Uppsala, Sweden). Further, 2 g were mixed with 28 mL of saturated magnesium sulphate (specific gravity 1.29, SVA, Uppsala, Sweden), to improve the detection of *Metastrongylus* spp. (Taylor et al., 2007). The samples were shaken vigorously, filtered through a sieve covered with gauze, mixed manually, transferred to a McMaster chamber, and after >3 min examined by light microscopy (×10, MC20, Micros Austria, St.Veit an der Glan, Austria). Eggs of *Ascaris* (*A.*) *suum*, *Metastrongylus* spp., *Trichuris* (*T.*) *suis*, strongyle-like eggs (*Oesophagostomum* spp., *Hyostrongylus rubidus* and *Globocephalus urosubulatus*), and coccidial oocysts were counted. One sample containing large amounts of coccidial oocysts was merged in an equal amount of 2% potassium dichromate (SVA, Uppsala, Sweden) and kept at ambient temperature for 14 d for sporulation and species identification. The $K_2Cr_2O_7$ was removed, and an equal amount of 4% formaldehyde (Bioreagens, Ellös, Sweden) was added. The samples were transported to SVA, the formaldehyde was removed by centrifugation, and a simple flotation using zinc sulphate (specific gravity 1.18, SVA, Uppsala, Sweden) was performed (Ministry of Agriculture Fisheries and Food, 1986). Species were identified according to Eckert et al. (1995).

2.6.3. Screening for parvovirus

One to five serum samples per herd were analyzed for the presence of parvoviral antibodies. Sera were primarily collected from sows that had given birth to mummified fetuses, and otherwise, in descending order, sows, gilts, or growers, were sampled. The blood samples, collected in vacuum tubes without additives, were stored at 4–8 °C overnight, sera were recovered, and frozen at −80 °C before analysis by a commercially available enzyme-linked immunosorbent assay (ELISA, Ingezim PPV Compac, Ingenasa, Madrid, Spain), according to the manufacturer's instructions.

3. Results

3.1. Husbandry

An overview of the characteristics of each herd can be found in the suppl. material, Table S.2. The husbandry varied over time and between age categories. Six herds kept all pigs confined, whereas the others mixed confinement, tethering and free-ranging. The housing included pens with walls of bricks, clay or wooden stockades, cemented, earthen or wooden floors, and roofs of iron sheets, straw, or no roof. The stocking density is shown in Table 1. The farrowing pens lacked rails and creep areas, but four herds sometimes provided bedding material (wood shavings, dried grass, banana fibers or rice husk). The pig areas were generally clean (average score 0.6), but three herds consistently kept the pigs in a dirty environment.

Table 1
The pig housing density in 16 of 20 studied farms in the district of Lira, presented as both kg live weight per m^2, and as m^2 per pig. Three herds did not confine the pigs and data was missing from one herd.

	Average	Span
Growers (3–60 kg; *n* = 14 farms)	16,4 kg/m^2 2,1 m^2/pig	2,1–40,4 kg/m^2 0,4–7,2 m^2/pig
Adults (*n* = 12 farms)	5,6 m^2/pig	2,1–14,4 m^2/pig

Table 2
Production figures calculated in 20 studied small-scale pig herds in the district of Lira, for the period July 2018 to June 2019.

	Average	Median	Min.	Max.	*n*H	*n*P
Average number of pigs (all categories)	18.6	5	1.7	148	20	–
Number of sows/year	2.6	1.3	0	13.5	19	–
Number of litters	4.1	2	0	24	17	82
Number of piglet born per litter	8.7	9	5	12	17	717
Number of piglets born alive per litter	8.2	8	4	12	17	671
Number of litters per sow/year	1.6	1.6	0	2.4	19	–
Farrowing interval (days)	188	177	141	236	8	31
Number of piglets born alive per sow/year	13.2	11.8	6.2	20.1	17	–
Percentage stillborn	6.6%	0%	0%	38.5%	17	717
Percentage abortions	2.4%	–	–	–	17	82
Weaning age (days)	43	45	17	59	16	64
Mortality suckling piglets	15.1%	11.1%	0%	30.0%	17	671
Mortality growers	9.7%	6.9%	0%	100%	20	694
Mortality female adults	7.9%	–	–	–	19	76
Pigs sold per sow/year	6.4	6	1.1	11.0	19	–
Growth 0–12 months (g/day)	101	103	26	189	20	105
Growth 0–3 months (g/day)	86	82	29	136	15	44
Growth 3–12 months (g/day)	107	93	6	220	19	79
Average Body Condition Score in adults	2.3	2.1	1.7	3.4	19	76

*n*H = number of herds included in the calculations.
*n*P=Number of pigs or litters included in the calculations.

3.2. Records and production figures

None of the herds kept good records (average score 0.7), and 65% (247/378) of the events were not recorded at all. Farrowings were most commonly recorded (61%) whereas estrus, weaning, buying pigs, deaths and diseases were rarely recorded (21–36%).

The small herds kept more gilts (71%) than the larger herds (29%; $P < 0.05$). During the study, farrowing occurred in 17 herds (Table 2), and two herds exceeded ten piglets born alive per litter, whereas seven herds produced <6 piglets/litter. Among the 101 piglets that died before weaning, 45 were crushed, 13 were weak, 11 died of cannibalism, six of diarrhea, five of trauma, ten of miscellaneous causes and 11 for unknown reasons. The mortality in growers was mainly due to diarrhea (46%; 31/67), and mostly occurring during the first month post weaning (52%; 35/67).

The measurements and body condition scoring at the secondary visits were insufficient and thus excluded from the calculations. Most herds ($n = 11$) sometimes kept very thin pigs, whereas two herds kept fat pigs, and both methods used for BCS correlated well ($P > 0.3$). The birth weights averaged 1.7 kg as recorded in eight herds, and the overall ADG (0–12 months) was 101 g/day (Fig. 2).

3.3. Feed

Most herds changed the feed due to seasonal or financial reasons and five herds sometimes kept their pigs free-ranging due to the lack of feed. In 19 herds, all pigs obtained the same feed (maize bran, sweet potato wines, "pig weed", and/or cassava), commonly supplemented with swills from *e.g.* schools, hotels, restaurants, alcohol production and the own household waste ($n = 16$). Only two farmers heated the swill before feeding. The amount of maize bran given varied between 0.3 and 4.8 kg/pig/day but in eight herds, the quantity stated was twice the quantity bought. In four herds, the quantity could not be evaluated. Raw cassava was common ($n = 9$), sometimes as the sole feed ($n = 2$). Three farmers always, and twelve sometimes, gave feed additives, mainly silver fish

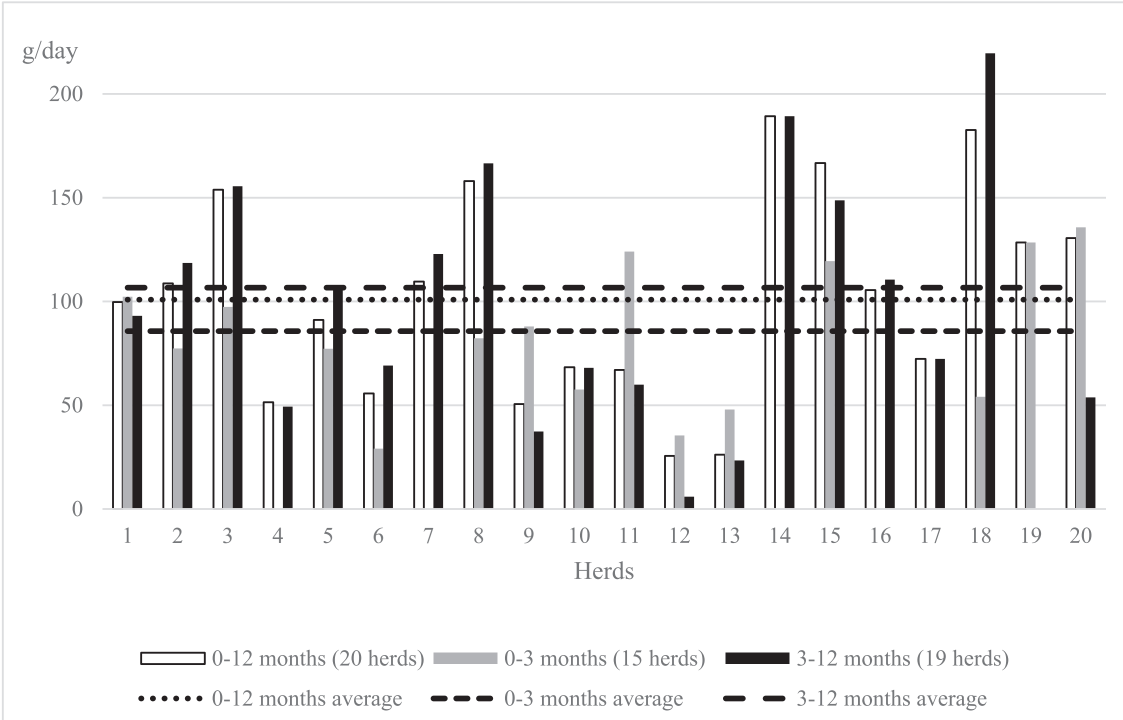

Fig. 2. The average daily gain in grams/day for different age categories, as measured by a weighing scale (≤10 kg) or by a measuring tape according to Mutua et al. (2011a), in 20 studied pig herds in the district of Lira.

("mukene"), but at times also salt, blood, fish or bone meal, snail shells, rice bran, sunflower cake or meal, red soil, soybean meal, broken maize, sweet potatoes or milk.

While feed and water were mostly given twice per day, two larger herds used water nipples and five herds only provided water once per day or not at all. Most pigs did not have access to water at the visits and dry, hard feces were commonly observed.

3.3.1. *Health issues related to nutrition*

Lack of water during hot weather was the presumed cause of death in one sow and several growers in two herds, one having water nipples that repeatedly were out of order. The three herds with the poorest overall growth had very poor feeding and in one of these, at least three pigs starved to death. The two other herds experienced severe diarrhea in growers. The mortality rates in growers in these herds ranged from 27.3% to 47.6%. The three herds with the best overall growth gave larger quantities of feed and while one of them experienced several diseases and a mortality of 8.2% in growers, the other two had no apparent health issues, except parasites, and no mortality in growers.

3.4. *Medical treatments*

Eighteen farmers consulted paraprofessional animal health workers, *i.e.* paraveterinarians, for treatment of sick pigs, routine treatments, castrations, or other consultations (≤14 times, median 4). Many inconsistencies were found between stated and conducted practices, and 11 farmers could neither describe the purpose nor the drug used.

In seven herds, paraveterinarians or the farmers themselves "prevented outbreaks" by treating the pigs with antibiotics such as oxytetracycline (OTC), penicillin+streptomycin (P-S) or sulfonamides (≤13 times, median 2). Other routine treatments included deworming (18 farms) with levamisole, ivermectin or, occasionally, albendazole (≤10 times, median 2), acaricide spraying (7 farms) with cypermethrin or amitraz (≤6 times, median 1), iron injections to 2–3 day-old piglets (5 farms) or to sows ante-partum (1 farm), and multivitamin injections (2 farms).

In 17 herds, sick pigs were treated with on average 1.4 drugs/treatment (≤16 times, median 5), using the anthelmintics (59/110 treatments) and antibiotics (68/110) stated above, or trimethoprim-sulfonamides. Also, uncharacterized treatments ("injection" or "treatment"; $n = 18$), acaricide sprays ($n = 10$) or herbs ($n = 3$) were used. Multivitamin injections were added in 10% of the treatments. Vaccines, non-steroid anti-inflammatory drugs or corticosteroids were not used.

3.5. *Reproduction routines*

3.5.1. *Estrus detection and service*

Five farmers required a certain size or age of the gilt at the first service. Boars were not used for heat detection, but one farmer mentioned the standing heat. Instead, estrus was detected by a swollen or red vulva, changed behavior or vulvar discharges.

Artificial insemination was not used. Mostly, females were moved to the boar at the first sign of estrus (9/18 herds) and stayed there for a day or less (9). Other farmers waited 1–2 days, kept the females with the boar for a longer period, or did not control the breeding. In one herd, the sows were still on heat after service. Using village boars and own boars were equally common, and some alternated these practices. The village boars were chosen based on their quality, proximity, availability or previous usage. Conversely, eight farmers used their males as village boars, serving foreign sows ≤14 times (median 2.5). At least seven herds practiced inbreeding, *e.g.* using littermates that were mated, the male were sold and the sow were kept until weaning, when two new piglets were retained and mated.

3.5.2. *Pregnancy, farrowing and lactation*

Pregnancy was detected by increasing udder and body size, lack of estrus, or increased feed intake. Imminent farrowing was detected by increased udder size and milk production (9/15 farmers) or behavioral changes, *e.g.* nesting behavior (10). Only five farmers were aware of the gestation length.

Before farrowing, ten farmers provided extra feed, water, or nesting material, or moved the sow. Most farmers monitored the farrowings, and four secluded the piglets during the farrowing. Other practices included removing the placentas (3 farmers), cutting the umbilical cords (2), ensuring suckling (2) or teeth cutting at 1–2 weeks of age (1). Cross-fostering was not performed. One herd tail-docked the pigs at 9 months of age, and ten herds castrated 1.5–6.5 month-old pigs (median 3.75 months) to promote growth, reduce sexual behavior or to enable customers to buy intact males. The farmers believed that the piglets would not survive an earlier castration and that older pigs recovered faster.

The average suckling period was 43 days (Table 2) but two herds sometimes separated the piglets from the sow parts of the day and one performed split weaning of retarded piglets. Most removed the piglets at weaning (8/17 herds), others moved the sow (4) or varied these practices (1), or the information was not obtained (4).

3.6. Biosecurity

Twelve farmers claimed to avoid contact with foreign pigs, nevertheless, ten herds kept pigs on free-range and 16 herds mixed their pigs with others at service. Only two herds kept their pigs strictly isolated. Five herds avoided feeding with pork. Nine herds bought in total 20 pigs during the study (≤8 pigs, median 2) from neighbors, neighboring villages, or other sub-counties.

Nine herds reportedly had some regulations for visitors, such as restricted access to the pigs or occasional hand-wash (2 herds). Three herds described, and one herd used, disinfectant boot baths but without prior cleaning of the boots, using Jik (sodium hypochlorite), Bio-Safe (a “cationic detergent”) or Norocleanse (unknown compound). The largest farm used dedicated, regularly washed, work-wear.

Six farmers described measures to separate their diseased pigs, such as handling them separately, providing sick pens, and releasing or selling the pigs. Dead pigs were buried (6 herds), thrown into the surroundings (7), burnt (2) or sold (2), irrespective of the cause of death. One herd separated age-categories by house, and one by pen, although pigs occasionally were able to run around. Two larger herds mixed the litters at weaning and in the remaining herds, age categories were not separated.

3.7. Pathogen screening

Ectoparasites were found in 13 herds, mainly lice (*Haematopinus suis*; 11 herds), but also fleas, *e.g. Ctenocephalides canis* (3), ticks (4), and “jiggers” (*Tunga penetrans*; 1). All 40 samples from 20 herds were negative for *S. scabiei*, despite signs indicative of mange in three pigs. Endoparasite eggs were found in 33/36 fecal samples from 19 herds (Table 3), the sugar-salt solution being superior to the magnesium sulphate in detecting eggs and oocysts of strongyles, *T. suis* and coccidia ($P < 0.05$). Antibodies to porcine parvovirus were found in 42% (18/43) of the individuals and 35% (7/20) of the herds. Positive herds kept more sows/year than negative herds (4.79 respective 1.31 sows; $P = 0.05$).

Table 3
Presence of endoparasite eggs or oocysts in different age categories of pigs in 20 studied herds in the district of Lira, as analyzed by a simplified McMaster flotation (Monrad et al., 1999). Three, two and one age category was sampled in two, twelve and six herds, respectively.

	Age category			
	Herd total $n = 20$	<4 months[1] $n = 10$	4–12 months $n = 16$	Sows/gilts[2] $n = 10$
Ascaris suum (% positive)	25%	10%	25%	10%
Absent	15	9	12	9
Low amounts (<500 EPG)	4	0	3	1
Moderate amounts (500–950 EPG)	0	1	0	0
High amounts (≥1000 EPG)	1	0	1	0
Trichuris suis	40%	10%	44%	0%
Absent	12	9	9	10
Low amounts (<500 EPG)	7	0	7	0
Moderate amounts (500–950 EPG)	0	0	0	0
High amounts (≥1000 EPG)	1	1	0	0
Strongyles	85%	60%	75%	90%
Absent	3	4	4	1
Low amounts (<500 EPG)	9	4	7	6
Moderate amounts (500–950 EPG)	4	2	2	1
High amounts (≥1000 EPG)	4	0	3	2
Metastrongylus spp.	30%	30%	13%	10%
Absent	14	7	14	9
Low amounts (<500 EPG)	6	3	2	1
Moderate amounts (500–950 EPG)	0	0	0	0
High amounts (≥1000 EPG)	0	0	0	0
Coccidia	80%	70%	75%	60%
Absent	4	3	4	4
Low amounts (<500 OPG)	5	3	4	3
Moderate amounts (500–950 OPG)	4	1	2	2
High amounts (≥1000 OPG)	7	3	6	1

EPG/OPG = Eggs/oocysts per gram.
[1] Weaned pigs [2]One month before to one week post-partum.

3.8. Clinical diseases

Eleven herds reported recurring or severe health problems involving several pigs. The main disorders detected or suspected were post-weaning diarrhea, ecto- and endoparasitosis (*e.g.* coccidiosis, trichuriasis and parasite-related pneumonia), parvoviral infection, erysipelas, skin lesions and injuries.

3.8.1. Systemic disorders

Three farmers suspected “outbreaks” of ASF in their free-range pigs. One sow in each of two herds, and six of their altogether 18 piglets, showed high fever, reddish skin, dullness, shivering, and inappetence. The herds initiated treatment with ivermectin respective OTC, but one sow and six piglets died, and the other sow was slaughtered. One remaining piglet developed arthritis, but the other 40 pigs in these herds remained healthy and five blood samples collected at the next primary visit were PCR-negative for ASF virus. In the third herd, one pig showed depression, cyanosis, and froth around the snout. The farmer immediately sold the pig and its pen mate, and the remaining, healthy, pig was also sold before sampling could be performed.

3.8.2. Organ-specific diseases

Severe post-weaning diarrhea with increased mortality rates occurred in three herds. In two larger herds, enterotoxigenic *E. coli* (ETEC) carrying genes for LT and STb toxins and adhesion factor F4 (K88), was associated with the diarrhea. The strains were resistant to four of eleven antibiotics tested (Table 4). In a small herd, all three pigs died post weaning and historically, eight of 12 weaned pigs from the two previous litters had died, despite treatment with levamisole.

Diarrhea with occasional deaths before weaning was reported in altogether seven herds. In three of these, a few-week-old, suckling piglets had steatorrhea and in one case, coccidial enteritis was identified (Fig. 3B). In another herd, a depressed, two-week-old piglet displayed nematode-related enteritis by histology (Fig. 3A).

Two herds reported severe diarrhea, retarded growth, and increased mortality rates in growers >1 month post weaning and in one, enteritis, typhlocolitis, and high amounts of *T. suis* (≤28.300 EPG) and coccidia

Table 4
Antibiotic susceptibility of *Escherichia* (*E.*) *coli* isolates cultured from four recently weaned diarrheic pigs in each of two herds, designated no. 5 and no. 18. The pigs in each herd are designated 0.1 to 0.4, respectively. Strains of enterotoxigenic *E. coli* are presented in bold. S=Susceptible, R = Resistant.

Antibiotic(s)	Break points, R	Sample							
		5.1*	5.2	5.3*	5.4*	18.1*	18.2	18.3	18.4*
Ampicillin or amoxicillin	>8	S	**S**	**R**	**R**	**R**	S	S	**R**
Cefotaxim	>0,25	S	**S**	**S**	**S**	**S**	S	S	**S**
Amoxicillin + clavulanic acid	>8/4	S	**S**	**R**	**R**	**R**	S	S	**R**
Colistin	>2	S	**S**	**S**	**S**	**S**	S	S	**S**
Nitrofurantoin	>64	S	**S**	**S**	**S**	**S**	S	S	**S**
Trimethoprim + sulphonamides	>0,5/9,5	S	**S**	**S**	**S**	**S**	S	S	**S**
Gentamicin	>4	S	**S**	**S**	**S**	**S**	S	S	**S**
Streptomycin	>16	S	**S**	**R**	**R**	**R**	S	S	**R**
Neomycin	>8	S	**S**	**S**	**S**	**S**	S	S	**S**
Tetracycline	>8	S	**S**	**R**	**R**	**R**	S	S	**R**
Enrofloxacin	>1	S	**S**	**S**	**S**	**S**	S	S	**S**

* Hemolytic isolates.

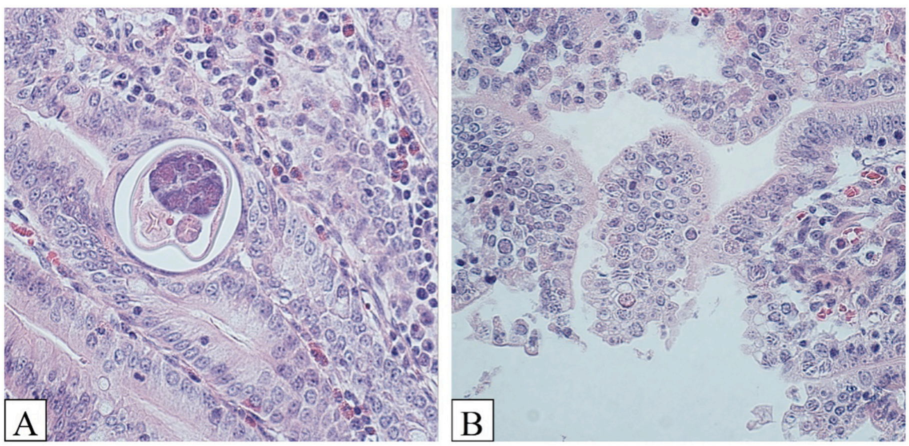

Fig. 3. Enteritis caused by endoparasites in two diarrheic suckling piglets from two of the 20 studied herds. A: Nematode resembling *Strongyloides ransomi*, and an increased number of eosinophils in the jejunum. B: Multiple intraepithelial coccidia of different developmental stages in the jejunum, HE 400×.

(≤54.400 OPG), identified as *Eimeria* (*E.*) *suis*, *E. perminuta* and *E. debliecki*, were found (Fig. 4). Six herds suffered from occasional diarrhea in growers, and in one pig, endoparasite-related enterocolitis was seen at necropsy. One herds also reported incidental vomiting and coughing.

In one of four herds reporting recurring or severe coughing, fecal egg counts displayed moderate to high numbers of *A. suum* and a few *Metastrongylus* spp. and at necropsy, mild interstitial pneumonia and eosinophilic bronchitis with nematodes in the lumen was found (Fig. 5). Coughing was incidentally reported in nine other herds, and in six of nine pigs, necropsied for other reasons, mild to moderate multifocal interstitial pneumonia, often with eosinophilia ($n = 5$), was noted by histology. Macroscopically, one pig displayed ~1 mm green-grayish firm nodules in the lungs. In six herds, panting related to hot weather, lack of shade, stress or pain was observed.

Two large herds reported recurring findings of mummified and/or stillborn fetuses, accounting for 9–16% of the total number of piglets born. In both herds, parvoviral antibodies were demonstrated.

One herd reported recurring suspected cases of erysipelas, with inappetence, arthritis, weakness, red skin lesions and death of some pigs. Treatment with OTC or P-S was generally successful.

Skin lesions were seen in all herds (Fig. 6) and commonly included lesions related to the tethering ropes, pruritus, reddish (sunburnt) ears, crusts/wounds, and rough or long hair-coat. Other observations included swinepox-like lesions (2 herds), ear necrosis in growers (1), single cases of tail necrosis (3), and a single sow with shoulder ulcers. One herd, mixing pigs in one pen with feeding troughs ≥8.4 cm/pig, presented with fighting wounds and occasional deaths. In another, a few growers had thickened, erythematous, encrusted skin and while no ectoparasites were found, *Staphylococcus sciuri*, resistant to oxacillin and fusidic acid, was cultured from beneath the crusts.

In addition, four herds reported unspecific inappetence and sometimes weakness in individual sows. Disorders of the locomotor system were incidentally reported, including sudden "paralysis" or uncoordinated movements, seemingly responsive to treatment with OTC, P-S or an "injection" (4 herds). Additionally, unsteady gait in severely retarded growers without other findings was observed in one herd, and chronic locomotor disturbances in a sow after fighting in another. One fat sow (BCS 4) suffered from post-partum dysgalactia and leg weakness, and all her piglets succumbed to diarrhea at three months of age.

4. Discussion

The VHHM approach generated in-depth knowledge on the diseases and identified both previously recognized constraints, as well as problems that have hitherto been overlooked, *e.g.* the poor reproductive management and performance. Notably, the diseases encountered in this study were similar to what may be found in pig production in any other part of the world (Mengeling et al., 2000; Fairbrother et al., 2005; Roepstorff et al., 2011; Zhang et al., 2012). The main infectious agents found included ecto- and endoparasites, ETEC and likely, parvovirus. Further, the poor biosecurity, the suboptimal reproductive management and the insufficient nutrition were of major importance. Thus, to interpret the findings and initiate targeted sampling, thorough knowledge about pig production, health and reproduction are prerequisites for practicing VHHM.

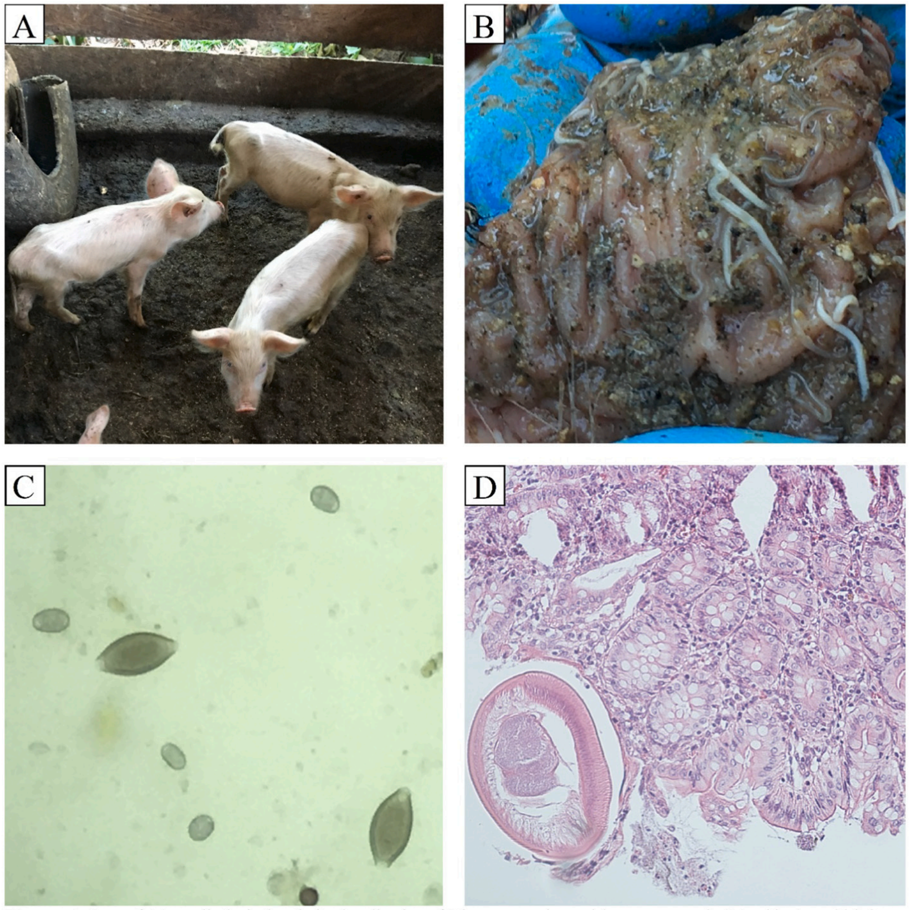

Fig. 4. One of 20 studied pig herds in the district of Lira presenting with poor growth (23 g/day) and high mortality rates (32.8%) in growers. A: 4-month-old pigs weighing on average 4.3 kg. B: Mild typhlocolitis and high numbers of *Trichuris* (*T.*) *suis* found at necropsy. C: Fecal flotation revealed high amounts of *T. suis* (≤28.300 eggs/g) and coccidia (≤54.400 oocysts/g) identified as *Eimeria* spp. D: Intraepithelial nematode in the colon, HE, 100×. A–D represent the same pigs.

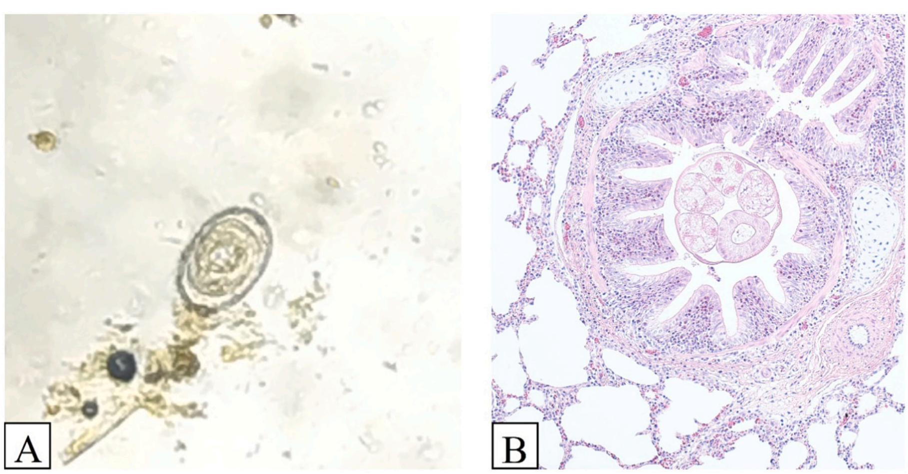

Fig. 5. One of 20 studied pig herds presented with clinically relevant cough. A: *Metastrongylus* spp. demonstrated by a simplified McMaster fecal flotation. B: Eosinophilic bronchitis and interstitial pneumonia with a nematode in the bronchial lumen in a pig subjected to necropsy due to diarrhea, HE 100×.

Three farmers described signs that could confer to ASF. The Ugandan farmers are much aware of the disease but may associate any severe febrile disease with ASF (Dione et al., 2014). Thus, since the laboratory analyzes failed to confirm the diagnosis in the surviving pigs and since the majority of the in-contact pigs remained healthy, other diseases cannot be ruled out. In particular, diseases such as *e.g.* erysipelas, that based on the anamnestic information was suspected in two herds, or porcine reproductive and respiratory syndrome, may be considered.

The biosecurity routines were poor and disease could easily be spread. In particular, the un-controlled movement of animals, *e.g.* through the use of village boars, pose important risks of disease transmission. As previously described (Kabuuka et al., 2014; Chenais et al., 2017), disinfectant boot baths were incorrectly used, thus being ineffective or even posing a risk for contamination (Amass et al., 2000).

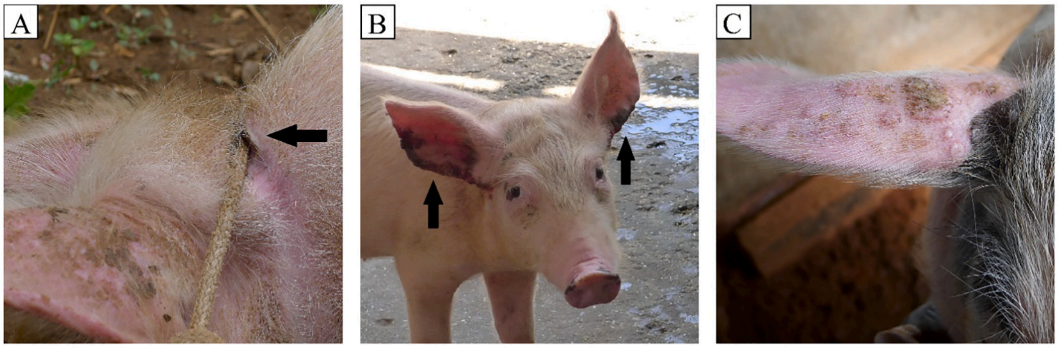

Fig. 6. Disorders of the integumentary system in three of the 20 studied pig herds (indicated by arrows). A: Lesion in the neck from a tethering rope. B: Ear necrosis in a grower. C: Swine pox-like lesions on the ear of a grower.

The reproductive performance was poor, and since the farrowing intervals only included sows that farrowed twice, the average interval might have been even longer. The poor reproduction was mainly due to lack of knowledge but possibly partly also due to the large number of gilts and the inferior breeds (Hughes, 1998; Hagan and Etim, 2019). Since the farmers mainly confided in unreliable vulvar signs (Sterning et al., 1994) and mated sows immediately upon estrus detection, they might have served the sows at inaccurate time-points, thus leading to return to estrus or to small litters (Soede et al., 1995; Steverink et al., 1997). The exact reasons for the few litters/sow/year, *e.g.* anestrus, missed estrus or repeated service, were not possible to identify, due to the lack of reliable information and thus, close observational studies on reproductive routines are needed. Overall, the farmers need to be trained in reproductive management, particularly in the service routines. Further, none of the farmers vaccinated against porcine parvovirus (PPV). The presence of PPV antibodies were considerably higher than in a previous study (Dione et al., 2018) and it is possible that the incidence have increased, as mirrored by the mummified fetuses and small litters, however, the methods used might also vary in sensitivity.

Diarrhea was a common and major health constraint, associated with high mortality rates in growers (9.7%), as compared to similar settings in Kenya (Wabacha et al., 2004) and intensive systems in other countries (INTERpig, 2017). By necropsies and targeted investigations, the two major causes were identified as endoparasites and ETEC. Post-weaning diarrhea associated with ETEC, found in the two largest herds, is mainly a problem in intensive pig production and related to *e.g.* pig density, suboptimal hygiene, feed and mixing of pigs (Lofstedt et al., 2002; Laine et al., 2008). In agreement with previous findings (Okello et al., 2015), the isolates were resistant to the most commonly used antibiotics tetracycline and streptomycin, as well as to amoxicillin.

Agreeing with previous studies (Nissen et al., 2011; Roesel et al., 2017), parasites were very common and overt clinical disease due to endoparasites was noted in at least four herds, suggesting that the deworming routines were ineffective. Coccidiosis, a common cause of diarrhea in suckling piglets (Niestrath et al., 2002; Zhang et al., 2012), was also demonstrated, while the species was not identified. Although generally not considered pathogenic (Lindsay et al., 1987; Koudela and Vítovec, 1992), the large numbers of *Eimeria* spp. might have aggravated the severe growth retardation and clinical disease attributed to *T. suis* in one herd. Ectoparasites, especially lice and fleas, were very common. In contrast to the findings in similar settings in Kenya (Wabacha et al., 2004), *S. scabiei* was not found. However, the mite can be difficult to detect and the results should be interpreted with caution.

Piglet mortality was lower than or comparable to other small- to medium-sized farms in sub-Saharan Africa (Wabacha et al., 2004; Biryomumaisho and Ogalo, 2007; Mutua et al., 2011b; Abonyi et al., 2012) and the main cause was crushing. Thus, the sows' condition and the pen constructions (size, bedding material, rails and a creep area) are areas that should be considered for improvement.

In agreement with previous findings (Ikwap et al., 2014b), cough was commonly reported, but generally did not seem to have a major impact. In one herd, however, coughing, weight loss and deaths were reported, possibly related to the findings of *Metastrongylus* spp., *A. suum* and nematode-related bronchitis. These findings, and the eosinophilia in the lungs of most necropsied pigs, suggest that endoparasites may be a common cause of coughing. However, the mild interstitial pneumonia found in most of the necropsied pigs might also have been caused by unidentified viruses.

The growth rates were very poor as compared to most intensively managed herds (INTERpig, 2017; Ramirez and Karriker, 2019), but were only slightly lower as compared to similar settings in East Africa (Wabacha et al., 2004; Mutua et al., 2012; Carter et al., 2013). While it is difficult to compare figures from various systems, the high birth weights and the large between-herd variation indicates a big potential for improvement. Further, the poor growth cannot be explained entirely by the breed, since indigenous breeds may grow considerably better (420 g/day; Holness et al., 2005). Instead, suboptimal feeding regimes were likely the main cause. Only feeding with maize may cause malnutrition and stunting (Lykke et al., 2013), and due to *e.g.* low digestibility and anti-nutritional factors (ANF), forage should not be used as the sole fodder (Kambashi et al., 2014). Cassava is very low in proteins and contains ANF, *e.g.* toxic cyanogenic glycosides (Manzano et al., 2007), possibly associated with statements that pigs refused to eat cassava for more than a few days. Notably, poor nutrition and water supply will not only affect growth but may also affect reproduction and health (Zak et al., 1997; Pedersen et al., 2002; Lykke et al., 2013; Langendijk et al., 2017; Costermans et al., 2019).

Farmers practiced castrations, tail-docking and teeth cutting without respect to animal welfare. Misconceptions about their effects were common and further communicated by the paraveterinarians. All of these practices should be performed before one week of age. Further, without proper feeding, castration will not increase the growth rates, as believed by the farmers. Tail-docking to prevent tail-biting, and teeth cutting to prevent fighting wounds in piglets, should not be advocated since neither of these issues were observed.

The record keeping was generally poor (average score < 1). This affects the possibility to retract relevant information and the ability to detect problems of *e.g.* reproduction. The many inconsistencies in various practices may be attributed to the lack of knowledge, social desirability bias (Paulhus, 1991), or changing conditions in the production. These inconsistencies might affect the results from *e.g.* cross-sectional studies.

5. Conclusion

In conclusion, veterinary herd health management was shown to be a useful tool to identify and evaluate constraints in pig herds in Uganda, especially in the light of the many inconsistencies found between reported and performed practices. Four major areas for future improvements were identified; nutrition, infectious diseases, biosecurity, and reproductive management. Overall, the lack of knowledge and good management practices was substantial. These constraints would not have been addressed by approaching the poor productivity by studying single infectious diseases. Thus, VHHM may play an important role in low-income countries to improve livestock health and productivity.

Disclosure

The researchers claim no conflict of interest.

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