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Sero-prevalence of *Taenia* spp. cysticercosis in rural and urban smallholder pig production settings in Uganda

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ABSTRACT

The pork tapeworm, *Taenia solium,* is prevalent in Uganda although the prevalence has not been determined in all areas of the country. A cross-sectional study, to determine the sero-prevalence of the parasite in pigs kept under rural and urban production settings, was carried out in three Ugandan districts, Masaka, Mukono and Kamuli. Serum samples from 1185 pigs were tested for the presence of *T. solium* cysticercosis antigen using the HP10 antigen-ELISA (Ag-ELISA) and the ApDia Ag-ELISA assays. Using parallel interpretation of the two tests showed lower levels of observed prevalence of *T. solium* in rural production settings (10.8%) compared to urban (17.1%). Additionally, Maximum Likelihood Estimation for evaluating assays in the absence of a gold standard, using TAGS on the R platform, estimated the true sero-prevalence to be lower in rural production setting, 0.0% [0.0–3.2%; 95% confidence interval (CI)] than in urban production setting, 12.3% (4.2–77.5% CI). When the sensitivity/specificity (Se/Sp) of the assays were estimated, assuming conditional independence of the tests, HP10 Ag-ELISA was more sensitive and specific [(Se = 53.9%; 10.1–100% CI), (Sp = 97.0%; 95.9-100% CI)] than the ApDia assay [(Se = 20.2%; 1.5–47.7% CI), (Sp = 92.2%; 90.5–93.9% CI)]. Subject to parasitological verification, these results indicate there may be a need to implement appropriate control measures for *T. solium* in the study areas.

1. Introduction

Taenia solium neurocysticercosis is considered a serious neglected, public health concern particularly in areas with poor standards of sanitation, public health and inappropriate animal husbandry practices (Secka et al., 2010; WHO, 2014). The pig is the primary intermediate host (porcine cysticercosis) and humans are the definitive hosts (taeniasis) (Soulsby, 1982). Dogs can also act as intermediate hosts (Ito et al., 2002), as can humans leading to human cysticercosis/neurocysticercosis; the latter being the leading cause of late onset epilepsy in pig-keeping communities in the developing countries (WHO, 2013).

In recent years the pig population in Uganda has grown (>15%), with an estimated total population of over 3.2 million pigs in 2008 (MAAIF, 2011). Factors including; their high fecundity and conversion rate, their early maturity, short generation interval and minimal space requirements, have made pigs an important source of livelihood for over 1.1 million resource-poor farmers in the rural and peri-urban communities as well as some urban centers in Uganda (Ouma et al., 2014a,b). This growth has resulted from increased demand for pork and pork products by consumers, with the consumption *per capita* of pork in Uganda being estimated at 3.4 kg/person/year (FAOSTAT, 2014). Various studies have associated growth in pig production and pork consumption in developing countries with increasing prevalence of *T. solium* cysticercosis, especially in pigs under poor management (Assana et al., 2010; García et al., 2003; Mwape et al., 2012; Praet et al., 2010). The parasite is known to be endemic in areas of Uganda (Nsadha et al., 2014; Waiswa et al., 2009).

In urban production settings in Uganda, pigs are commonly kept in corrals whereas pigs in rural areas are kept under extensive

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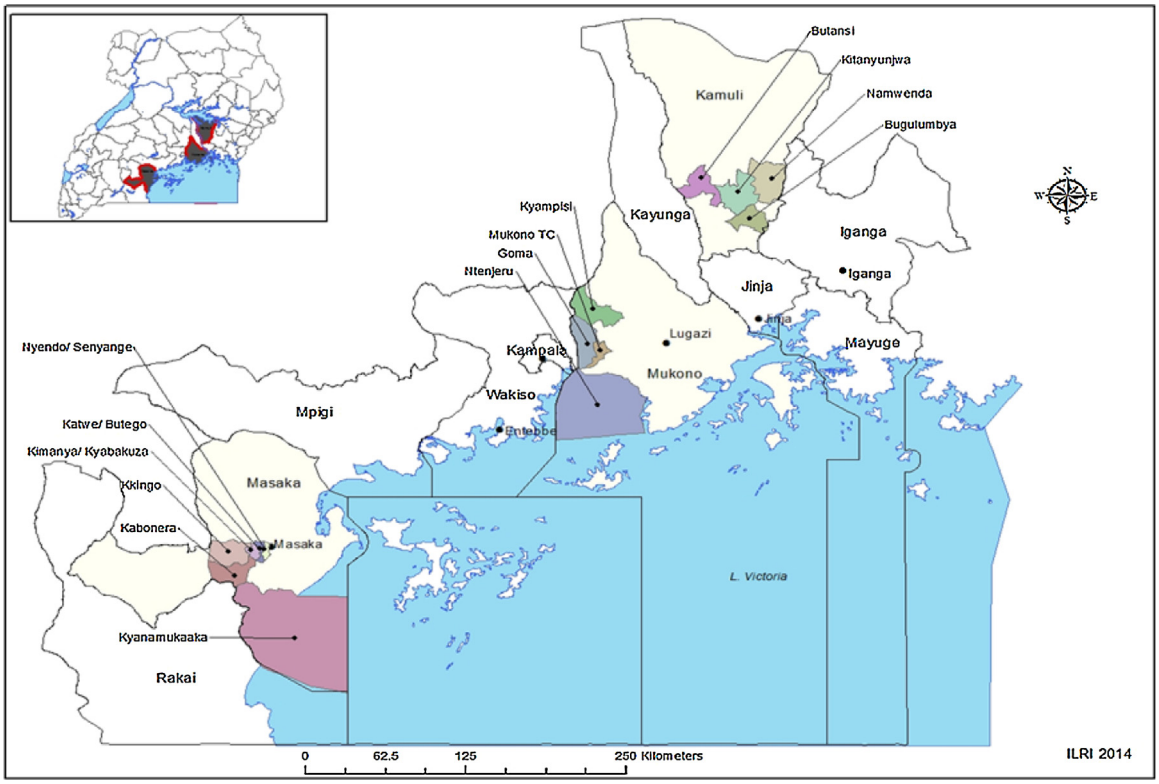

Fig. 1. A map of Uganda showing Masaka, Mukono and Kamuli districts and study areas within these.

management systems (Dione et al., 2014). The later system may promote parasite transmission (Eshitera et al., 2012; Pondja et al., 2010).

The main objective of this study was to determine and compare the sero-prevalence of *T. solium* cysticercosis in the rural and urban smallholder pig production settings of three districts in Uganda, where there was little previous knowledge regarding prevalence of the parasite.

The study has also demonstrated the use of the Maximum Livelihood Estimation (MLE) method to estimate prevalence, sensitivity and specificity in the absence a gold standard diagnostic test (Dohoo et al., 2009).

2. Materials and methods

2.1. Site selection

A cross-sectional survey was conducted from April to August 2013 in Masaka, Mukono and Kamuli districts of Uganda by the Smallholder Pig Value Chain Development (SPVCD) project and its partners (Ouma et al., 2014a,b). The selection of participating sites utilised a geographical targeting protocol to prioritise location based on their pig population density, human poverty levels and proximity to urban centers. Details of the site selection process was described elsewhere (Dione et al., 2015).

In order that we might compare rural and urban production settings, value chain domains that were identified by Ouma et al. (2014a,b) as rural production for rural consumption; and rural production for urban consumption were classified as "rural" and urban/peri-urban production for urban consumption was classified as "urban" production. Note that Kamuli district was not considered to include any form of urban production setting. Fig. 1 shows the districts and sub-counties where pigs were sampled.

2.2. Sample size determination

The original sample size was calculated to estimate district-level prevalence of undefined diseases, i.e., not specifically for this study, and assuming an infinite population (no recent census data) using the formula adopted from Thrusfield (2007) as follows: $n = [Z^2P(1\text{-}P)]/d^2$ Where: n is the required sample size; Z is the multiplier from a standard normal distribution (1.96) at a probability level of 0.05; *P* is the estimated prevalence which is most conservatively estimated to be 50% considering that there is no reliable prevalence data for *T. solium* cysticercosis in pigs in two of the districts under study (Mukono and Masaka) and d is the desired precision for the estimate (+/− 5%). A sample size of 384 pigs was required for the study in each district; in the field, a total of 375, 408, and 402 pigs were sampled in Masaka, Kamuli and Mukono, respectively. The actual number of pigs sampled in Masaka was lower than the required sample size because of the harsh working conditions experienced due to heavy rain. Post-hoc power calculations for this study, using Stata 10.0 (Stata Corp, LP USA) indicated a power of 75% to show significantly different prevalence levels between rural and urban production systems at the 5% level of significance. The study observed prevalence of 10.8% (100/927) in rural and 17.1% (44/258) in urban settings, implying that the selected sample size was reasonable. However, this power has not been adjusted for potential intra-cluster (village) correlation.

2.3. Household and pig selection

A list of all pig keeping households was generated by local partners in each village. The study households were then randomly selected using computer-generated random numbers. Apparently healthy pigs over three months of age were selected. Pregnant sows or sows with litters under two months old were excluded. One pig fulfilling the inclusion criteria was randomly selected for blood collection.