Acta Parasitologica
https://doi.org/10.1007/s11686-020-00295-y

ORIGINAL PAPER

Detection of Porcine Cysticercosis in Meat Juice Samples from Infected Pigs

Justine Daudi Maganira[1,4] · Winifrida Kidima[2] · Chacha John Mwita[3] · Johan Höglund[4]

Received: 8 June 2020 / Accepted: 3 October 2020
© Witold Stefański Institute of Parasitology, Polish Academy of Sciences 2021

Abstract

Background Seroprevalence of porcine cysticercosis has been generally studied using enzyme-linked immunosorbent assays (ELISA) detecting either antigens or antibodies in sera. However, serum is not always readily available. The objective of this study was to assess the diagnostic potential of meat juice in detecting porcine cysticercosis using a cysticercosis antibody ELISA.

Methods Sera and meat juice samples from 13 different organs/tissues were collected from nine pigs naturally infected with cysticercosis and from six uninfected pigs reared under hygienic conditions. The sensitivity of the cysticercosis antibody ELISA in detecting porcine cysticercosis in meat juice samples was compared to that in serum samples from the same pigs.

Results Using sera, cysticercosis was detected in all nine pigs harbouring cysticerci, but not in those reared under hygienic conditions. The sensitivity of the ELISA was highest in meat juice extracted from the diaphragm (100%), heart (89%) and neck muscle (78%) of the nine infected pigs, whereas it varied between 0 and 44% in the other samples.

Conclusion To the best of our knowledge, this is the first study for *T. solium* cysticercosis serology to use meat juice. Our results show that meat juice from pig carcass organs or muscles is a promising diagnostic specimen for the detection of porcine cysticercosis. More studies including a large sample size of pigs with varying degrees of cysticercosis infection are needed to further prove this concept.

Keywords Pigs · *Taenia solium* porcine cysticercosis · Meat juice · Serum · ELISA · Tanzania

Introduction

Porcine cysticercosis is a zoonotic disease caused by the larval form of *Taenia solium*. The disease affects the pig farming industry through losses due to veterinary costs, reduced market value and reduction of pork in the food chain due to the condemnation of heavily infected pig carcasses [1, 2]. The cestode *T. solium*, which also infects humans, is most prevalent in low-income countries of Asia, Africa and Latin America [3, 4]. Porcine cysticercosis is endemic in almost all sub-Saharan African countries due to free-range pig production and poor sanitation [3, 5].

Consumption of undercooked pork from infected pigs may lead to taeniasis in humans, which is a risk factor for porcine and human cysticercosis transmission. Thus, the safety of pork entering the food chain plays a key prophylactic role against taeniasis and cysticercosis. The presence of strict meat inspection and quality control should reduce the rate of *T. solium* infection. However, meat inspection in many areas in endemic low-income countries is often nonexistent or not strictly performed. For example, studies have shown that conventional meat inspection methods, such as *postmortem* examination may underestimate the prevalence of porcine cysticercosis because of latent infections [6–8]. Lack of specific control procedures and proper meat inspection may pose health risks to consumers because infected

✉ Justine Daudi Maganira
justine.maganira@sua.ac.tz

1 Department of Biosciences, Sokoine University of Agriculture, P.O. Box 3038, Morogoro, Tanzania

2 Department of Zoology and Wildlife Conservation, University of Dar es Salaam, P.O. Box 35064, Dar es Salaam, Tanzania

3 Department of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam, P.O. Box 35064, Dar es Salaam, Tanzania

4 Department of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences, P.O. Box 7036, 750 07 Uppsala, Sweden

Published online: 15 February 2021

pork may enter the food chain unnoticed [6]. To guarantee the provision of safe pork to consumers, it is important to invest in effective and reliable diagnostic techniques.

Although serology using serum samples is considered effective for porcine cysticercosis surveillance programmes over conventional inspection methods [6–8], serum samples are not always readily available when pork is sold for consumption. Thus, it would be useful to explore other diagnostic specimens from pig carcass and evaluate their suitability as alternative for the detection of porcine cysticercosis. The use of pig carcass samples that can be easily obtained after slaughter might be efficient for the continuous monitoring of the burden of disease among pig herds from endemic areas.

The aim of this study was to evaluate the performance of meat juice from various tissues of the pig carcass as diagnostic specimens for the detection of porcine cysticercosis using a commercially available cysticercosis enzyme-linked immunosorbent assay (ELISA). Information on the diagnostic potential of meat juice as a diagnostic specimen may be useful for epidemiological studies, disease monitoring, and in the evaluation of control programmes.

Materials and Methods

Source of Sample Animals

Blood and tissue samples were obtained from slaughtered pigs in rural villages of the Kongwa district in Dodoma region and from Nyandira in the Mvomero district in Morogoro region, Tanzania. Pigs with *T. solium* cysticerci were identified via *antemortem* lingual palpation and then confirmed to be infected following visual inspection for cysticerci at slaughter and later by sequencing [9]. All pigs ($n=9$) harbouring cysticerci were free-ranged and obtained from villages in Kongwa. Similarly, pigs reared under more strict hygienic conditions with no cysticerci ($n=6$) were obtained from Mvomero. Oral consent was sought from pig owners before sample collection.

Sample Collection

From each pig, about 4 ml of auricular blood was collected into a BD-vacutainer tube fitted with 20G 1.5″ needles (Becton Dickinson, USA) and stored at about 4 °C into a cooler box before serum extraction.

After careful visual inspection of the carcass, about 100 g of tissue from the same parts of the brain, diaphragm, eye, fore, and hind leg muscles, heart, kidney, liver, lung, masseter, neck muscles, spleen, and tongue were collected into clean plastic containers and thereafter after transportation stored at − 20 °C before further processing. In total, 9 blood and 117 tissue samples were collected from the pigs naturally infected with cysticercosis. Similarly, a total of 6 blood and 78 tissue samples (control samples) were collected from 6 pigs uninfected pigs (without any visible cysticerci) following the same procedures.

Sera and Meat Juice Recovery

Cysticercosis-positive serum samples were recovered in the laboratory from the collected blood within 6–8 h after blood collection by centrifuging at 2000×*g* for 10 min and then stored in labelled 1.8-ml cryogenic vials (Thermo Fischer Scientific, Denmark) at − 20 °C until further analysis. Special containers for meat juice collection (CC Plast A/S, Hillerød, Denmark) was used to extract meat juice from frozen tissue samples cut into small pieces and left to thaw for 5–6 h at room temperature. Meat juice was recovered from all tissues, but the brain, eye, and spleen gave about threefold lower meat juice than other tissues. The collected meat juice samples were then stored at − 20 °C before further analysis.

Determination of Specific Antibodies Against Porcine Cysticercosis

A commercial enzyme-linked immunosorbent assay (ELISA) kit (VetLine Taenia IgG ELISA, NovaTec Immundiagnostica GMBH, Germany), referred herein as cysticercosis antibody ELISA, was used for the qualitative determination of specific antibodies against porcine cysticercosis infection in pig serum and meat juice samples following test protocol provided by the manufacturer. According to the manufacturer, the sensitivity and specificity of the VetLine Taenia IgG ELISA using serum samples are greater than 95% but it may cross-react with other *Taenia* spp. Serum samples from the same pigs were used as the reference standard for the corresponding meat juice tissue samples. Sera and meat juice were diluted with sample dilution buffer in the ratio of 1:100 and 1:10, respectively, followed by thorough mixing by vortexing. The samples were then incubated for 1 h at 37 °C. After incubation, each well was washed three times with 300 µl of washing solution. After washing, 100 µl of VetLine Taenia Protein AG Conjugate was added into all wells except for the substrate blank well, covered with aluminium foil and incubated at room temperature for 30 min in a dark cabinet. This was followed by washing and dispensing 100 µl of TMB Substrate Solution into all wells and incubating for 15 min in a dark cabinet at room temperature. The reaction was stopped by the addition of 100 µl stop solution. The optical density (OD) values were read at 450 nm with a spectrophotometer (iMark™ Microplate Reader, Bio-Rad). For all the reactions, the run validation criteria (test validity), as set by the manufacturer, were met. The test results were expressed as negative or positive based on NovaTec Units (NTU) which were calculated from

the equation: [sample (mean) OD/cut-off OD] × 10 = NTU, where cut-off is the mean OD value of the cut-off control determinations. A sample with NTU below 9 was considered negative, whereas a sample with NTU above 11 was considered positive for porcine cysticercosis. Samples' reactions with NTU between 9 and 11 were considered as doubtful and were retested.

Data Analysis

Descriptive statistics were computed in Microsoft Excel 2016 for Windows. For both serum and meat juice samples, the sensitivity of the cysticercosis antibody ELISA was calculated as the probability of a positive ELISA test among pigs with cysticercosis [10, 11]. Kruskal–Wallis nonparametric test was performed in GraphPad Prism version 8.0.1 (La Jolla California, USA) to compare antibody concentration in meat juice from different tissues of pigs with or without visible cysticerci.

Results

Characteristics of Examined Pigs

The age of the pigs ranged from 6 to 24 months covering both sexes. Typical *T. solium* cysticerci were present in most of the organs and/or muscles except for the kidney, liver, lung, and spleen from the pigs in Kongwa (Table 1). Of the 9 pigs, 6 were heavily infected with a total of more than 30 cysticerci, while 3 had a light infection, with less than 10 visible cysticerci in their respective tissues (Fig. 1). Out of 117 tissue samples collected from these pigs, 68 (58%) had visible cysticerci while 49 (42%) had no cysticerci (Table 1). No cysticerci were found in the control pigs from Mvomero.

Prevalence of Porcine Cysticercosis in Serum and Meat Juice Samples

All serum samples from the nine pigs from Kongwa with cysticerci tested positive at a dilution of 1:100 in the cysticercosis antibody ELISA. In contrast, all serum samples from the six pigs from Mvomero with no visible cysticerci were negative.

Meat juice samples from organs or muscles with or without typical cysticerci of *T. solium* tested positive or negative in the cysticercosis antibody ELISA (Table 1). Of all 117 samples from pigs with cysticerci in any organ, 45 (38%) tested positive while 72 (62%) tested negative at a sample dilution of 1:10. Out of 68 meat juice samples from tissues with visible cysticerci, 41 (60%) tested positive for porcine cysticercosis. The carcass samples that most often tested positive were diaphragm followed by heart and neck muscles. Of 49 meat juice samples extracted from tissues of pigs with cysticercosis but from carcass samples without visible cysticerci (kidney, liver, lung, and spleen), only 4 (8%) samples from the lungs were positive while 45 (92%) were negative (Table 1). Similarly, all 78 meat juice samples from the 6 pigs with no cysticerci tested negative in the cysticercosis antibody ELISA.

Sensitivity and Specificity of the Cysticercosis Antibody ELISA Using Meat Juice Samples

The sensitivity of the ELISA test in the different meat juice samples in relation to serum was highest for the

Table 1 Cysticercosis ELISA test results for meat juice samples from pigs with cysticercosis (*CP* cysticerci present, *ab+* antibody ELISA positive, *ab−* antibody ELISA negative, *CA* cysticerci absent, $_x$ no value, % percent)

Organ	Overall			Cysticerci present						Cysticerci absent					
	Pigs	ab+	% ab+	CP	% CP	ab+	ab−	% ab+	% ab−	CA	% CA	ab+	ab−	% ab+	% ab−
Brain	9	4	44	8	89	4	4	50	50	1	11	$_x$	1	$_x$	100
Diaphragm	9	9	100	9	100	9	$_x$	100	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$
Eye	9	4	44	6	67	4	2	67	33	3	33	$_x$	3	$_x$	100
Fore leg	9	3	33	6	67	3	3	50	50	3	33	$_x$	3	$_x$	100
Hind leg	9	3	33	7	78	3	4	43	57	2	22	$_x$	2	$_x$	100
Heart	9	8	89	9	100	8	1	89	11	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$
Kidney	9	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	9	100	$_x$	9	$_x$	100
Liver	9	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	9	100	$_x$	9	$_x$	100
Lung	9	4	44	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	9	100	4	5	44	56
Masseter	9	$_x$	$_x$	7	78	$_x$	7	$_x$	100	2	22	$_x$	2	$_x$	100
Neck	9	7	78	8	89	7	1	88	13	1	11	$_x$	1	$_x$	100
Spleen	9	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	$_x$	9	100	$_x$	9	$_x$	100
Tongue	9	3	33	8	89	3	5	38	63	1	11	$_x$	1	$_x$	100

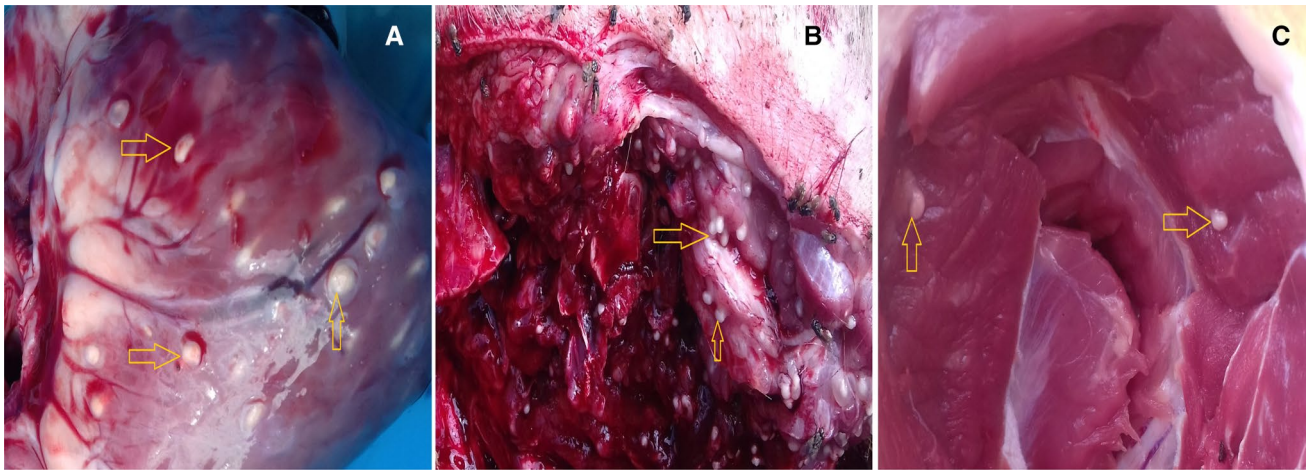


Fig. 1 Pig heart (**a**) and neck muscle (**b**) heavily infected and hind leg muscle (**c**) lightly infected with cysticerci

Table 2 Sensitivity of cysticercosis antibody ELISA comparing results from meat juice samples and with sera from the same animals as the positive reference (*TP* true positive, *FN* false negative, *TN* true negative, *FP* false positive)

Sample	TP	FN	TN	FP	Sensitivity (%)
Brain	4	5	6	0	44
Diaphragm	9	0	6	0	100
Eye	4	5	6	0	44
Fore leg	3	6	6	0	33
Hind leg	3	6	6	0	33
Heart	8	1	6	0	89
Kidney	0	9	6	0	0
Liver	0	9	6	0	0
Lung	4	5	6	0	44
Masseter	0	9	6	0	0
Neck	7	2	6	0	78
Spleen	0	9	6	0	0
Tongue	3	6	6	0	33

diaphragm (100%), followed by the heart (89%) and neck muscles (78%), whereas it ranged between 0 and 44% in the other tissues (Table 2). The specificity of cysticercosis antibody ELISA using serum or meat juice samples was 100%. The average OD for positive and negative serum samples was 0.472 (range 0.373–0.537) and 0.089 (range 0.009–0.160), respectively. In contrast, the average OD for positive and negative meat juice samples was 0.259 (range 0.057–0.570) and 0.109 (range 0.055–0.260), respectively. There was no significant difference in the mean OD values in serum and meat juice samples from carcass tissues except for meat juice from the hind leg, kidney, liver, masseter and spleen (Table 3).

Discussion

In the present study, we evaluated for the first time the performance of meat juice from various organs or tissues of the pig carcass as alternative diagnostic specimens for the detection of porcine cysticercosis using a cysticercosis antibody ELISA. Although meat juice samples have been used for the detection of other zoonotic parasites such as *Toxoplasma gondii* in pigs [12], the suitability as a diagnostic specimen for detection of porcine cysticercosis has according to our knowledge never been evaluated before. However, the use of meat juice in the detection of cysticercosis among taeniid tapeworms has been reported before by Abuseir et al. [13] in a study involving cattle experimentally and naturally infected with *T. saginata* cysticercosis.

Our results in the present study show that the sensitivity of the cysticercosis antibody ELISA in detecting porcine cysticercosis using meat juice from diaphragm (100%), heart (89%) and neck muscle (78%) was similar or close to that found in serum samples, the reference specimens (100%). The specificity of the cysticercosis antibody ELISA using either sera or meat juice samples was 100%. This suggests that meat juice especially from the diaphragm may be useful for epidemiological studies, long-term disease monitoring in pig herds and in the evaluation of porcine cysticercosis control programmes given its high sensitivity and specificity.

Similar to the results of the present study, a higher sensitivity ranging between 83 and 100% of an antibody ELISA employing HP6-2 and TS45S-10 peptides in the detection of bovine cysticercosis using meat juice from undefined tissues with *T. saginata* cysticerci has been reported [10]. In addition, the performance of meat juice from some pig carcass samples in detecting porcine cysticercosis using antibody ELISA in our study showed relatively higher sensitivity (except for meat juice from the kidney, liver, masseter and

Table 3 Antibody levels expressed as optical density (OD) values for serum and meat juice samples from pigs with visible *T. solium* cysticerci (*Min* minimum, *Max* maximum, *SD* standard deviation, *CI* confidence interval, *OD* optical density, *MRD* mean rank difference)

Sample	Min	Max	Mean	SD	Lower 95% CI	Upper 95% CI	Mean OD values multiple comparisons		
Serum	0.373	0.537	0.472	0.055	0.430	0.515	Comparison pairs	MRD	p value[a]
Brain	0.058	0.457	0.254	0.168	0.125	0.383	Serum vs. brain	54.72	0.135
Diaphragm	0.397	0.570	0.444	0.061	0.397	0.491	Serum vs. diaphragm	8.78	> 0.999
Eye	0.072	0.428	0.234	0.166	0.107	0.362	Serum vs. eye	58.22	0.065
Fore leg	0.094	0.428	0.229	0.144	0.118	0.339	Serum vs. fore leg	54.61	0.138
Heart	0.187	0.533	0.394	0.090	0.325	0.464	Serum vs. heart	21.11	> 0.999
Hind leg	0.059	0.422	0.208	0.156	0.088	0.329	Serum vs. hind leg	63.06	0.023
Kidney	0.081	0.348	0.187	0.084	0.123	0.252	Serum vs. kidney	63.39	0.021
Liver	0.108	0.355	0.203	0.089	0.135	0.272	Serum vs. liver	59.89	0.046
Lung	0.092	0.517	0.306	0.174	0.173	0.440	Serum vs. lung	36.06	> 0.999
Masseter	0.057	0.361	0.137	0.102	0.059	0.215	Serum vs. masseter	82.00	0.000
Neck	0.083	0.462	0.351	0.137	0.246	0.457	Serum vs. neck	30.56	> 0.999
Spleen	0.119	0.330	0.184	0.064	0.136	0.233	Serum vs. spleen	61.00	0.036
Tongue	0.068	0.474	0.229	0.164	0.103	0.355	Serum vs. tongue	56.83	0.088

spleen) (Table 2) than the sensitivity of detecting porcine cysticercosis using tongue inspection (21%) or routine meat inspection (22%) estimated using a Bayesian approach [8]. Nevertheless, the sensitivity of meat inspection method has been reported to be high only when partial or full carcass dissection are performed [13, 14].

Our study indicates that the cysticercosis ELISA is a sensitive and reliable technique for the detection of porcine cysticercosis using serum. The study also demonstrates that the diagnostic performance of meat juice from diaphragm is equally sensitive and specific as that of serum although at a lower dilution of 1:10 as compared to that of serum (1:100). However, the sensitivity and mean OD values in meat juice from some of the carcass tissues were in most cases poorer than those in serum samples (Tables 2,). Detection sensitivity may be improved by adjustment for the dilution factor as it has also been previously reported in a study involving the detection of antibodies from serum and meat juice of pigs experimentally infected with the protozoan, *T. gondii* [12, 15], as well as in the detection of bovine cysticercosis on meat juice in cattle experimentally infected with bovine cysticercosis [10]. Findings from this study suggest careful consideration in the selection of carcass tissues for meat juice extraction for *T. solium* diagnostic procedures.

It should also be noted that porcine cysticercosis was mainly detected in meat juice from tissues with several visible cysticerci (60%), whereas samples from pigs with light infections were mostly not detected (Table 1). This indicates that antibody levels are related to the number of cysticerci present in the carcass. Based on sensitivity measures in this study, the diaphragm followed by the heart might be the most suitable organs for meat juice extraction as compared to the other tissues investigated herein. In addition, meat juice from the neck muscles showed to have both reasonably high sensitivity (78%) and antibody levels almost similar to meat juice from the heart, which also suggests the suitability of this tissue in detecting porcine cysticercosis.

A limitation with the cysticercosis antibody ELISA is that it may cross-react with other *Taenia* spp. This can be addressed by confirming suspected *T. solium* cysticerci from infected pigs by molecular analysis as indicated in this study [9]. Another limitation of this study may be a relatively smaller sample size of pigs naturally infected with cysticercosis ($n = 9$).

Conclusions

The results presented herein indicate that meat juice collected from the diaphragm is a promising diagnostic specimen in the detection of porcine cysticercosis. The potential of meat juice from the diaphragm as a diagnostic specimen may be useful for long-term epidemiological studies, disease monitoring, and in the evaluation of control programmes. However, more studies on a relatively large sample size of pigs with varying degrees of porcine cysticercosis infection are needed to further prove this concept. The viability of cysticerci from infected pigs was not investigated in this study, thus it will be worthy in future studies to investigate the correlation between test results and cysticerci status (viable or degenerated).

Acknowledgements The authors' acknowledge the funding provided by Swedish International Development Cooperation Agency (SIDA) for the bilateral research programme 2015–2020 titled "To Enhance Food Security, Safety and Value Addition in Tanzania'' carried out in a joint research and training programme between the University of Dar

es Salaam (UDSM), Tanzania and Swedish University of Agricultural Sciences (SLU), Sweden.

Author Contributions JDM: conceived field and laboratory design, data collection, analysis and interpretation, and manuscript writing. WK: conceived field, data interpretation and final manuscript revision. CJM: conceived field design. JH: conceived study design, leading the research team and final manuscript revision.

Funding The work funded by SIDA under SIDA-Tanzania Bilateral Programme, Food Security Sub-programme (Contribution No. 5410004501).

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Statement The study protocol was approved, in compliance with the Tanzania's Animal welfare act of 2008, by the Research Ethics Committee of the Sokoine University of Agriculture (RPGS/R/ETH-ICS/32).

Informed Consent Pig owners voluntarily agreed and gave their oral informed consent for data collection from their slaughtered pigs.

References

1. Praet N, Speybroeck N, Manzanedo R, Berkvens D, Nforninwe DN, Zoli A et al (2009) The disease burden of *Taenia solium* cysticercosis in Cameroon. PLoS Negl Trop Dis 3:e406. https://doi.org/10.1371/journal.pntd.0000406
2. Nkwengulila G (2014) The financial costs associated with porcine cysticercosis and epilepsy in Iringa rural district. Health 6:2959–2965. https://doi.org/10.4236/health.2014.621334
3. Assana E, Lightowlers MW, Zoli AP, Geerts S (2013) *Taenia solium* taeniosis/cysticercosis in Africa: risk factors, epidemiology and prospects for control using vaccination. Vet Parasitol 195:14–23. https://doi.org/10.1016/j.vetpar.2012.12.022
4. Flisser A, Sarti E, Lightowlers M, Schantz P (2003) Neurocysticercosis: regional status, epidemiology, impact and control measures in the Americas. Acta Trop 87:43–51. https://doi.org/10.1016/S0001-706X(03)00054-8
5. Phiri IK, Ngowi H, Afonso S, Matenga E, Boa M, Mukaratirwa S et al (2003) The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. Acta Trop 87:13–23. https://doi.org/10.1016/S0001-706X(03)00051-2
6. Thomas LF, Harrison LJS, Toye P, de Glanville WA, Cook EAJ, Wamae CN et al (2016) Prevalence of *Taenia solium* cysticercosis in pigs entering the food chain in western Kenya. Trop Anim Health Prod 48:233–238. https://doi.org/10.1007/s11250-015-0949-6
7. Shonyela SM, Mkupasi EM, Sikalizyo SC, Kabemba EM, Ngowi HA, Phiri I (2017) An epidemiological survey of porcine cysticercosis in Nyasa District, Ruvuma Region, Tanzania. Parasite Epidemiol Control 2:35–41. https://doi.org/10.1016/j.parepi.2017.09.002
8. Dorny P, Phiri IK, Vercruysse J, Gabriel S, Willingham AL, Brandt J et al (2004) A Bayesian approach for estimating values for prevalence and diagnostic test characteristics of porcine cysticercosis. Int J Parasitol 34:569–576. https://doi.org/10.1016/j.ijpara.2003.11.014
9. Maganira JD, Mwang'ondea BJ, Kidima W, Mwita CJ, Höglund J (2019) Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district. Tanzania Parasite Epidemiol Control 7:e00123. https://doi.org/10.1016/j.parepi.2019.e00123
10. Abuseir S, Kühne M, Schnieder T, Klein G, Epe C (2007) Evaluation of a serological method for the detection of *Taenia saginata* cysticercosis using serum and meat juice samples. Parasitol Res 101:131–137. https://doi.org/10.1007/s00436-006-0429-z
11. Parikh R, Mathai A, Parikh S, Sekhar GC, Thomas R (2008) Understanding and using sensitivity, specificity and predictive values. Indian J Ophthalmol 56:45–50. https://doi.org/10.4103/0301-4738.37595
12. Wallander C, Frössling J, Vågsholm I, Burrells A, Lundén A (2015) "Meat juice" is not a homogeneous serological matrix. Foodborne Pathog Dis 12:280–288. https://doi.org/10.1089/fpd.2014.1863
13. Abuseir S, Epe C, Schnieder T, Klein G, Kühne M (2006) Visual diagnosis of *Taenia saginata* cysticercosis during meat inspection: Is it unequivocal? Parasitol Res 99:405–409. https://doi.org/10.1007/s00436-006-0158-3
14. Chembensofu M, Mwape KE, Damme I Van, Hobbs E, Phiri IK, Masuku M et al (2017) Re-visiting the detection of porcine cysticercosis based on full carcass dissections of naturally *Taenia solium* infected pigs. Parasit Vectors 10:572. https://doi.org/10.1186/s13071-017-2520-y
15. Forbes LB, Parker SE, Gajadhar AA (2012) Performance of commercial ELISA and agglutination test kits for the detection of anti-*Toxoplasma gondii* antibodies in serum and muscle fluid of swine infected with 100, 300, 500 or 1000 oocysts. Vet Parasitol 190:362–367. https://doi.org/10.1016/j.vetpar.2012.06.040

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.