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Ineffectiveness of meat inspection in the detection of *Taenia solium* cysticerci in pigs slaughtered at two abattoirs in the Eastern Cape Province of South Africa

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ABSTRACT

Porcine and human cysticercosis, caused by the larval stage of tapeworm *Taenia solium*, is a zoonosis in southern Africa and known to be endemic in South Africa, mainly in Eastern Cape Province. No efforts to control or eradicate this parasite have been made, despite the increasing occurrence in most Eastern Cape districts, except for routine meat inspection at local abattoirs. The parasite poses a potentially serious agricultural problem, public health risk and economic loss amongst Eastern Cape smallholder pig production communities. The objective of this study was to determine the effectiveness of routine meat inspection for the detection of porcine cysticercosis in pigs from rural smallholder/subsistence production systems in Eastern Cape Province villages. The effectiveness of meat inspection, by registered meat inspectors, in the detection of pigs infected with *T. solium* cysts was assessed and compared with whole carcass dissection as the "gold standard" method. The commercial antigen enzyme linked immunosorbent assay (B158/B160 Ag-ELISA) kit screened all the slaughtered animals. The proportion of pigs found infected with *T. solium* cysts, as measured by meat inspection, was lower (5%, 9/180) than with carcass dissection (18.9%, 34/180) and B158/B60 Ag-ELISA test (21.6%, 38/176). Four out of 180 carcasses were heavily infested with *T. solium* cysts, evenly distributed throughout the carcasses, to a level impossible to enumerate. Of the remaining 176 carcasses, approximately 526 cysticerci, distributed at various anatomical regions of the pig, were counted during carcass dissection. Sites with higher cyst counts, such as the back and hind leg, do not form part of the normal meat inspection regime. The level of agreement (Kappa statistic) between dissection (gold standard) and meat inspection of the two districts was negative (−0.1955). There was a slight agreement in the Kappa statistic (0.0328) between dissection and B158/B60 Ag-ELISA. This study confirms that current meat inspection procedures alone are not sufficiently sensitive to detect all cases of porcine cysticercosis at the abattoirs and require modifications, or should be supplemented by other methods. A risk-based meat safety assurance system, such as HACCP, that considers specific food safety aspects before and after the abattoir (point of slaughter) should be followed. Before slaughter, aspects such as origin, husbandry practices and on-farm animal health control should be considered; after slaughter, the abattoir should inform the next entity in the supply chain of the limitations of meat inspections and the real meaning of an "Approval" stamp. New validated testing methods that can be routinely used should be developed, and government should develop policies and legislation that promotes a risk-based meat safety assurance system throughout the food supply chain.

1. Introduction

Taenia solium taeniasis/cysticercosis was identified by the World Health Organization (WHO) as one of the 20 Neglected Tropical Diseases (NTDs), ranked first on the global scale of foodborne parasites by the Food and Agricultural Organization (FAO) of the United Nations and the WHO in 2014 (Gabriël et al., 2016). Endemic areas are characterised by the existence of free-ranging pigs, which have access to human faecal matter (Garcia et al., 2011; Wardrop et al., 2015). Poor sanitary conditions, free-roaming of domestic pigs, lack of disease awareness by the communities, and control by government health and agriculture officials play an important role in the perpetuation of *T.*

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solium taeniasis and cysticercosis in sub-Saharan Africa (Phiri et al., 2003; Ngowi et al., 2013).

In most endemic countries, existing legislations require infected pigs to be condemned and/or destroyed by veterinary officers. However, there is lack of, or challenges in veterinary enforcement and often the infected carcasses are marketed and consumed by the public (Assana et al., 2013). South Africa is one of the Southern African countries that recognised human cysticercosis many decades ago, however a study conducted in 21 villages of the Eastern Cape indicated the parasite was present in OR Tambo and Alfred Nzo Districts at an average true prevalence of 64.6% (Krecek et al., 2008). A survey using computerised tomography (CT) scans revealed 61.1% of patients (69/113) had neurocysticercosis-associated epilepsy and the prevalence was highest in the 10 to 19 year old age group (12.4% of the total) (Ocana et al., 2009).

Tongue palpation and carcass inspection during slaughter are commonly used for ante and post-mortem diagnosis respectively, although these have shown poor sensitivity (Dermauw et al., 2016). Legislation on routine meat inspection to detect *T. solium* cysticercosis in South Africa and Zimbabwe is focused on incisions of the dorsal and ventral parts of the carcass (Rhodesia, 1995; South Africa, 2000). These include incisions of the external masseters (Muscular masseter) of the head, triceps brachii muscles on each front leg, muscular part of the diaphragm and the interventricular septum of the heart to open the ventricles, and two additional vertical cuts into the split septum (Rhodesia, 1995; South Africa, 2000).

Additional inspection of suspect carcasses, referred to as secondary meat inspection, can increase the sensitivity of inspection. In terms of the South African Red Meat Regulations, promulgated under the Meat Safety Act 40 of 2000, a carcass, head and red offal found to be infested with one or more parasitic intermediate stages, which may be alive or calcified, must be condemned. In pigs, two additional incisions parallel and proximal to the original incisions must be made into each Musculas triceps brachii. If the infestation is not excessive, the carcass and organs may be passed on condition they undergo treatment at minus 18 °C for 72 h or minus 10 °C for 10 days.

As an alternative to meat inspection, serological assays designed to detect *T. solium* antigens or antibodies have been used and have shown a higher sensitivity compared to meat inspection (Lightowlers et al., 2016). Enzyme-linked immunosorbent assay (ELISA) and enzyme-linked immunoelectrotransfer blot techniques (EITB) are the most appropriate tools for measuring exposure to *T. solium* in sero-epidemiological surveys in pigs and for confirmation of *T. solium* as the etiological agent of epilepsy in humans ((Dorny et al., 2003; Jayashi et al., 2014). In studies conducted in some sub-Saharan African countries, including South Africa, Ag-ELISA testing showed reliable results (Komba et al., 2013). However, this test showed cross-reaction between *T. solium* and *Taenia. hydatigena* since it is genus, not species specific (Dermauw et al., 2016).

The objective of this study was to determine the effectiveness of routine meat inspection in the detection of *T. solium* cysts in pigs from rural smallholder/subsistence pig production villages of the Eastern Cape Province in comparison to carcass dissection considered as the "gold standard" and the enzyme-linked immunosorbent assay (B158/B60 Ag-ELISA).

2. Methodology

2.1. Study areas

The study was conducted in two areas of Eastern Cape Province, namely the OR Tambo and the Alfred Nzo District municipalities. The two districts were chosen based on previous studies by Krecek et al. (2008) where the prevalence of *T. solium* cysticercosis was reported to be high. Fig. 1 illustrates the location of the two study districts and villages where study pigs were purchased in the Eastern Cape Province of South Africa.

OR Tambo district has a population of about 1,364,943 and covers 12096 km^2 (4670 sq. mi) on the coastline (South Africa, 2013). The district is made up of five local municipalities, namely King Sabata Dalindyebo, Nyandeni, Mhlontlo, Port St Johns and Ingquza Hill. The Alfred Nzo district has a population of approximately 801,344 and covers 10731km^2 (4143 sq. mi). The district comprises Matatiele, Ntabankulu, Mbizana and Umzimvubu local municipalities.

Both districts are mainly communal land. The rural villages and traditional homesteads are scattered and far apart from each other, with most households practicing small-scale subsistence farming (van Tol et al., 2016). The majority of households cultivate crops, such as maize and small grains on small areas of land around the homes, and/or are involved with extensive livestock rearing, which includes cattle, sheep, goats, pigs and chickens on communal grazing areas. Pigs are owned in varying numbers by each household and are free roaming.

Similar to other provinces of South Africa, the Eastern Cape has a traditional structure consisting of the House of Traditional Leaders, such as Kings, Chiefs and Community Leaders. These structures do not form part of the government structures, although they are given powers in terms of the Traditional Leadership and Governance Framework Act (Act 41 of 2003). Municipalities must consult with traditional leaders to carry out the mandate of local government (Steyn et al., 2014); traditional leaders have always been part of African government as they look after the welfare of local communities (Mathenjwa and Makama, 2016).

2.2. Study design

The design was a combination of a quantitative and experimental study. The procedures followed to obtain data for the study are shown in Fig. 2.

2.3. Ethical approval

Written approval for the study was obtained from the Tshwane University of Technology, with ethics clearance from the Faculty of Science Committees for Research Ethics (Reference number FCRE2016/06/001SCI), Animal Research Ethics Committee (Reference number AREC2016/05/001) and the House of Traditional Leaders to conduct the study in their areas of jurisdiction. The latter required two presentations, emphasising their roles in guiding communities regarding their customs and traditions and their consent to administer questionnaires to the community and use of their animals in the study.

On a national level, the Directorate of Veterinary Services of the National Department of Agriculture, Forestry and Fisheries granted permission to conduct the study in terms of Section 20 of the Animal Disease Act 35 of 1984 (South Africa, 1984). This section gives permission to investigate experiment or research with any vaccine, serum, toxic, anti-toxic or other biological product consisting or originating wholly or partially of, or from, any micro-organism, or of or from the glands, organs, fluid or any other part of an animal or parasite. On a provincial level, the Department of Rural Development and Agrarian Reform of the Eastern Cape Province of South Africa granted permission for transporting and slaughter of the pigs for the project's purpose, and confirmed in writing that the districts in which the study was conducted were not under quarantine or other veterinary restrictions for any controlled diseases, including porcine cysticercosis.

2.4. Procurement of pigs from villages of the study areas

South African statistics (South Africa, 2016) categorised households into clusters based on the number of pigs they kept (Table 1). The sample size was determined by considering the estimated number of pigs per household per village. Table 1 depicts the number of households per category for the respective study areas and the number of pigs sampled per household.

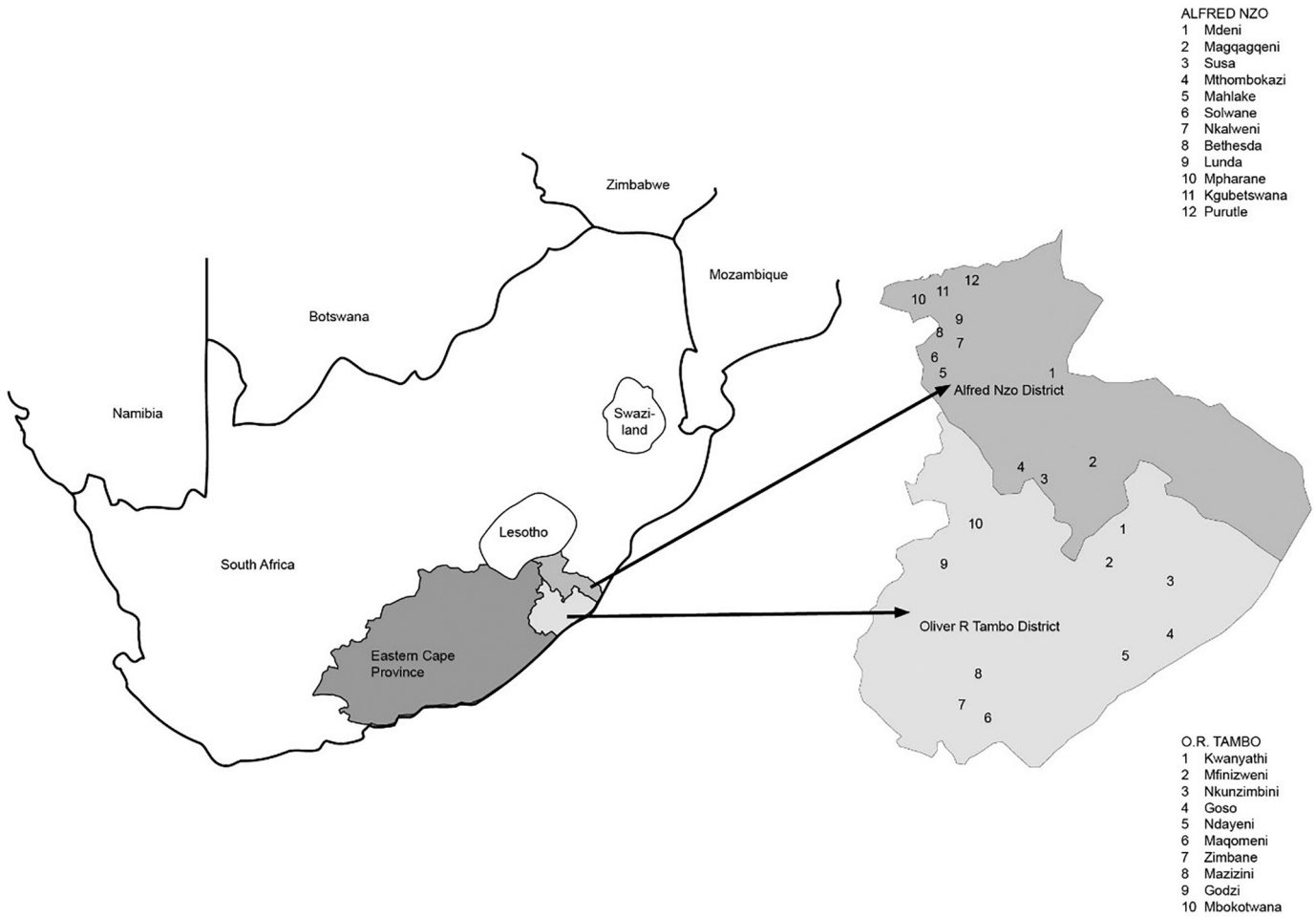

Fig. 1. Location of the two study districts and villages where study pigs were purchased from the Eastern Cape Province of South Africa.

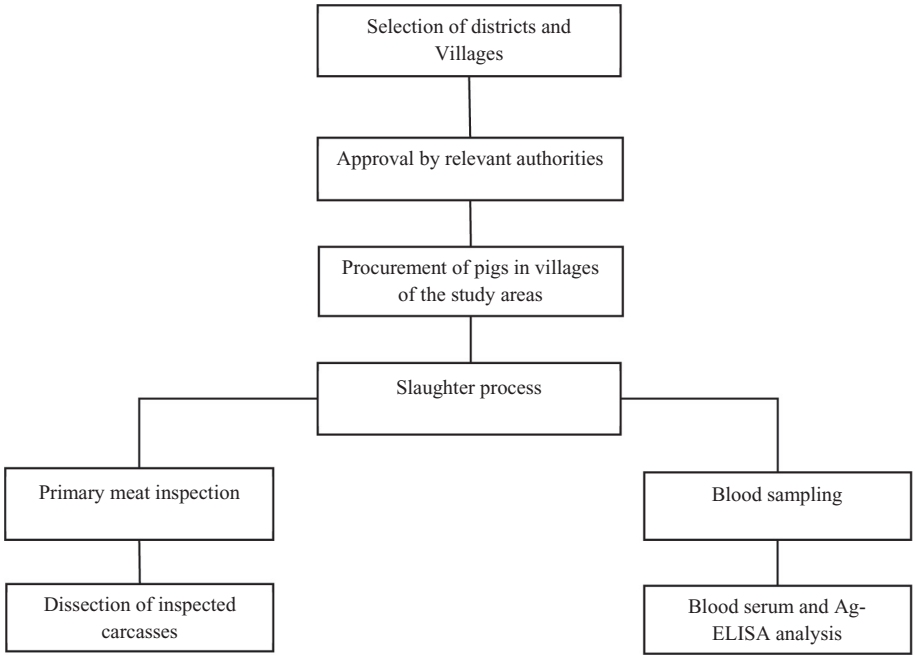

Fig. 2. Schematic diagram of the design of the study.

Table 1
Procedure followed in selection of pigs for the detection of *Taenia solium* cysts in two districts of the Eastern Cape Province of South Africa.

O.R.Tambo District			Alfred Nzo District		
Randomly selected villages of O.R Tambo District			Random selected villages of Alfred Nzo District		
1–10 pigs per household 30 households (N = 3504) were randomly selected from which one pig was sampled per household	11–100 pigs per household 30 households (N = 171) were randomly selected from which one pig was sampled per household	> 100 pigs per household 30 households (N = 35) were randomly selected from which one pig was sampled per household	1–10 pigs per household 30 households (N = 3788) were randomly selected from which one pig was sampled per household	11–100 pigs per household 30 households (N = 87) were randomly selected from which one pig was sampled per household	> 100 pigs per household 10 households (N = 11) were randomly selected from which three pigs was samples per household

Table 1 summarises the number of randomly selected villages per category of pig numbers per household.

From August to October 2016, 180 pigs were purchased from emerging pig owners from 10 villages in the OR Tambo (n = 90) and 12 villages in the Alfred Nzo (n = 90) District municipalities. The selected villages lie within ± 100 km radius from Umtata (high throughput) and Matatiele (low throughput) abattoirs situated in the King Sabata Dalindyebo and Matatiele Local Municipalities, respectively (Fig. 1). Purchased pigs, identified by ear tags, were transported to Umtata (High throughput) or Matatiele (Low throughput) abattoirs for slaughter and meat inspection.

2.5. Pig slaughter and meat inspection

Pigs were kept overnight at the abattoirs and slaughtered as part of the normal process. During the slaughter, blood samples for Ag-ELISA testing (see 2.7) were taken from the pigs directly during bleeding, centrifuged and the serum decanted into vials, refrigerated and delivered overnight to the parasitology laboratory of the Onderstepoort Agricultural Research Council in Pretoria, South Africa. Meat inspection was conducted on all carcasses by registered meat inspectors, in accordance with the requirements stated in the red meat regulations promulgated under the Meat Safety Act 40 of 200 (South Africa, 2000). There was no interference with the meat inspection process or judgement made by the inspectors. Meat inspection included incision of the *T. solium* cysticerci preference sites, such as masseter muscles, triceps brachii muscles, tongue, heart and diaphragm and *T. hydatigena* preference sites, which included the liver and peritoneum (Lightowlers et al., 2016; Chembensofu et al., 2017). Incisions made during meat inspection to detect the presence of cysts in the carcass are shown in Fig. 3a–b. Incisions were also made in the heart and diaphragm, with additional incisions made in the M. triceps brachii on detection of cysts in any of the aforementioned incision cites.

Results of the meat inspection were recorded for each carcass, irrespective of whether it was approved, conditionally approved or rejected. After carcass inspection was completed, the researcher investigated the peritoneal cavity and viscera (liver and omentum) to verify whether there were any *T. hydatigena* cysts (Dermauw et al., 2016).

2.6. Carcass dissection

The refrigerated carcasses were transported to the Tsolo Agricultural College (approximately 50 km from Umthata and 190 km from Matatiele) for dissection. Dissection was conducted as a gold standard to detect *T. solium* cysts infestation (Lightowlers et al., 2015; Chembensofu et al., 2017). Irrespective of the outcome of the primary meat inspection, all carcasses were subjected to whole carcass dissection. Dissection was carried out by the research team, with assistance from senior students registered for the National Diploma for Animal Health with the Tsolo Agricultural College after thorough training on carcass dissection by a veterinarian who was part of the research team. Full carcasses, together with the heart, liver, lungs, tongue and brain were sliced. Although the dissection slices made during this study ranged between 2 and 3 mm, there must be cognisance that cysts could be missed especially in very low infection or when cysts are very small (Chembensofu et al., 2017). Kidneys, spleen, stomach and intestines were not inspected as they remained at the abattoirs. It was observed that all cysts were viable because of a defined cystic structure with clear liquid content. There were no semi-solid contents or inflammatory scars noticed (Vargas-Calla et al., 2016).

2.7. Enzyme-linked immunosorbent assay (B158/B60 Ag-ELISA)

The monoclonal antibody-based parasite antigen test B158/B60 Ag-ELISA (apDia bvba, Hertoginstraat 82, 2300 Turnhout, Belgium) was

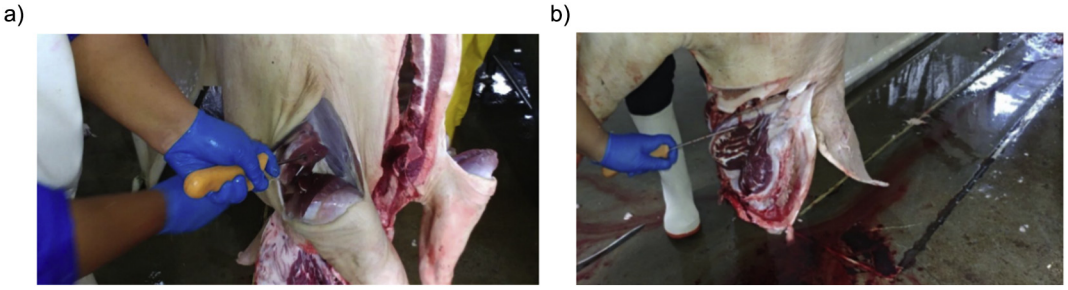

Fig. 3. a–b: Incisions made on the muscles of the carcass during routine meat inspection.

used to detect exposure to *T. solium* in all the slaughtered pigs used for this study (Dorny et al., 2004). Positivity to cysticercosis was determined as per the apDia kit manufacturer's instructions.

3. Results

3.1. Prevalence of T. solium cysts in slaughtered pigs by carcass dissection, meat inspection and B150/B60 Ag-ELISA

There was an estimated 25,772 and 30,151 mixed breed pigs in Alfred Nzo District and OR Tambo District, respectively (South Africa, 2016). As these farmers do not keep records of their pigs' ages, they were requested to supply us with pigs not less than six months of age, according to their estimation. Some of the pigs appeared small for the estimated age, probably because of poor nutrition. They further advised us they were unlikely to keep pigs for > 2 years. Table 2 shows the number of pigs slaughtered from villages of the two districts and the proportion of positive animals through meat inspection, carcass dissection and B158/B60 Ag-ELISA. There was a significant difference in the prevalence of *T. solium* cysticercosis between Alfred Nzo (0.8%) and OR Tambo (6.9%) districts as detected by meat inspection ($p < .05$), but no significant difference in prevalence by carcass dissection and ELISA. The uneven distribution of pigs purchased from the respective villages was influenced by the village size, availability of pigs and willingness of farmers to sell.

The overall proportion of pigs found with *T. solium* cysts, measured by meat inspection and carcass dissection as the gold standard for the two districts, is shown in Table 2. OR Tambo district had a higher proportion of pigs with cysts by carcass dissection (22.2%: 20/90) compared to Alfred Nzo district (15.6%: 14/90), and the same for meat inspection, (8.9%: 8/90) and (1.1%: 1/90) respectively. The level of agreement (Kappa statistic) between dissection (gold standard) and meat inspection of the two districts was negative (−0.1955), which is an indication of disagreement between the two methods. There was a minimal agreement in the Kappa statistic (0.0328) between dissection and B158/B60 Ag-ELISA.

Seven carcasses with *T. hydatigena* cysticerci (3.8%) were observed during meat inspection. Although Ag-ELISA cannot confirm co-

Table 2
Percentage (%) of pigs with *Taenia solium* cysts detected through meat inspection and carcass dissection and those that tested positive by B158/B60 Ag-ELISA from two districts of the Eastern Cape Province of South Africa.

Village name	No of pigs purchased	Carcass dissection (gold standard)	Meat inspection		B150/160 Ag-ELISA	
		No positive/Tested (%)	No positive/Tested (%)	Kappa Coefficient	No positive/Tested (%)	Kappa Coefficient
Alfred Nzo district						
Bethesda	4	0/4	0/4		0/4	
Kgubetswana	4	0/4	0/4		0/4	
Lunda	2	0/2	0/2		0/2	
Mdeni	6	0/6	0/6		2/6 (33.3)	
Mahlake	10	5/10 (50.0)	0/10		1/10 (10.0)	
Mthombokazi	9	3/9 (33.3)	0/9		3/9 (33.3)	
Magqagqeni	7	2/7 (28.6)	0/7		1/7 (14.3)	
Nkalweni	2	0/2	0/2		0/2	
Mpharane	27	1/27 (3.7)	0/27		5/27 (18.5)	
Purutle	2	0/2	0/2		0/2	
Solwane	7	1/7 (14.3)	0/7		1/7 (14.3)	
Susa	10	2/10 (20.0)	1/10 (10.0)		4/10 (40.0)	
Total	90	14/90 (15.6)	1/90 (1.1)	−0.2213	17/90 (18.9)	0.0425
OR Tambo district						
Godzi	9	1/9 (11.1)	0/9		1/7 (11.1)	
Goso	5	0/5	0/5		0/5	
Maqomeni	5	1/5 (20.0)	0/5		0/5	
Mbokotwana	7	1/7 (14.3)	1/7 (14.3)		0/6	
Mfinizweni	8	3/8 (37.5)	0/8		1/8 (12.5)	
Mazizini	3	1/3 (NC)[a]	0/3		0/3	
KwaNyathi	27	3/27 (11.1)	3/27 (11.1)		7/27 (25.9)	
Ndayeni	4	2/4 (50.0)	1/4 (25.0)		2/4 (50.0)	
Nkunzimbini	16	7/16 (43.8)	3/16 (18.8)		9/16 (56.3)	
Zimbane	6	1/6 (16.7)	0/6		1/5 (16.7)	
Total	90	20/90 (22.2)	8/90 (8.9)	−0.1748	21/86[b] (24.4)	0.0256
Total for 2 districts	180	34/180 (18.9)	9/180 (5)	−0.1955	38/176 (21.6)	0.0328

[a] NC = Not calculated due to sample size < 4.
[b] Ag-ELISA was done on 176 pigs only, since serum from four pigs were missing – refer villages Godzi (−2), Mbokotwana (−1) and Zimbane (−1).

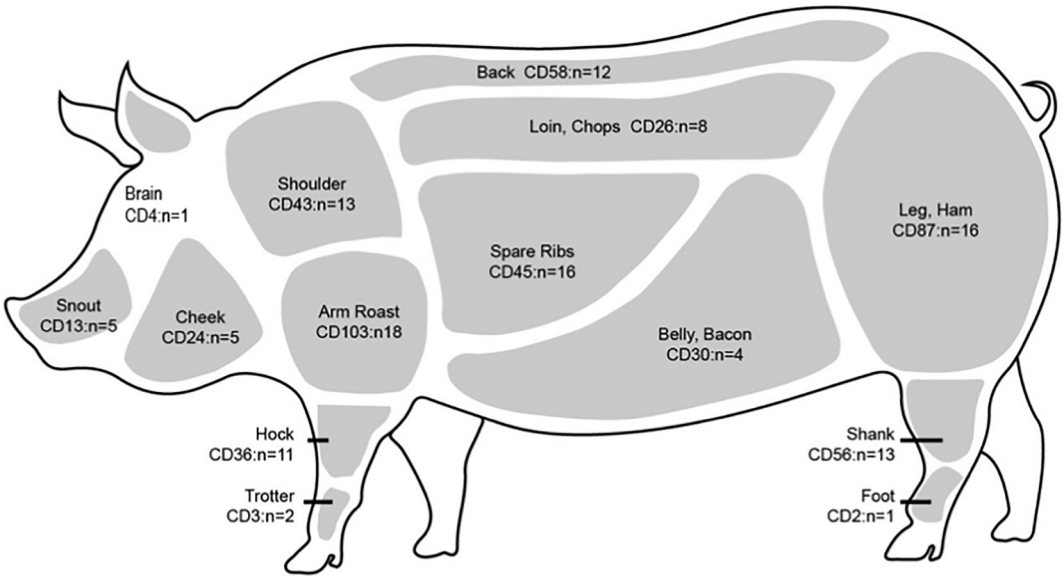

Fig. 4. Number of cysts detected during carcass dissection (n = 176) in relation to the retail cuts/portions of the carcass. Note: CD = Cysts detected; n = number of carcasses where cysts were detected at this region.

infection, since it is not species specific, three of these carcasses (1.7%) were found to be positive for *T. solium* by Ag-ELISA testing only, one (0.5%) confirmed by dissection only and one (0.5%) confirmed by Ag-ELISA and dissection, while the remaining two were not detected during either dissection or Ag-ELISA.

3.2. Distribution of T. solium cysts in the pig carcass, by carcass dissection

Out of 180 carcasses, four were heavily infested with *T. soilum* cysts, evenly distributed throughout the carcasses to a level impossible to enumerate. Fig. 4, as representation of retail cuts/portions of a carcass instead of specific muscles, illustrates only 30 of the remaining 176 carcasses were detected by dissection, with approximately 526 cysticerci distributed across various retail cuts/portions.

The number of cysts recovered from the different regions of the carcass is shown in Fig. 4. In addition, cysts were detected in the heart (3 pigs highly infested, 3 with 1 cyst each, and 1 with 3 cysts), tongue (2 pigs highly infested, 1 with 4 cysts, and 1 with 1 cyst) and brain (1 pig with 4 cysts, 3 with 1 cyst each, 1 with 2 cysts). No cysts were detected in the livers and lungs. In total, of 34 carcasses detected to have cysts through dissection, 16 carcasses also had cysts in the heart, tongue and brain, as indicated above. According to our study, the detected cysts do not represent an average number of pigs but the number of carcasses out of 34 that were found positive during dissection.

4. Discussion

The performance of routine meat inspection in this study indicated a low prevalence of porcine cysticercosis from slaughtered pigs compared to carcass dissection; this is in agreement with previous studies (Dorny et al., 2004; Phiri et al., 2006). Of the 343 pigs slaughtered in a Kenyan abattoir, no pigs were found positive for *T. solium* cysts during meat inspection, while a 34% prevalence was recorded on the same pigs by HP10 Ag-ELISA test (Thomas et al., 2016). Stark et al. (2014) believed the meat inspection protocol for the detection of *T. solium* cysts was not sufficiently sensitive to detect cysts in low infections. In this study, only 5% (9/180) of the pigs had cysts through meat inspection compared to 18.9% (34/180) through carcass dissection, which is considered the "gold standard" for the determination of true prevalence for total dissection of the carcass (Alcobedes et al., 2010). Of importance, is the prevalence was higher in OR Tambo (8.9%: 8/90) district than Alfred Nzo (1.1%: 1/90). This was expected as most pigs from OR Tambo district were free-range and at a higher risk of exposure to contaminated human faeces due to poor sanitation (Pawlowski et al., 2005; Bulaya et al., 2015).

Carcass dissection showed greater sensitivity for the detection of *T. solium* cysts, and cysts detected in the entire carcasses were viable, as described by (Phiri et al., 2006). Although meat inspection is focused on the dorsal and ventral parts, carcass dissection in this study revealed cysts could be located in any part of the carcass. This is an indication that retail cuts/portions, of which some are expensive compared to others, are also affected.

Parts of the carcass not normally inspected during meat inspection but which showed a high cyst count were muscles of the hind leg (ham), back, shank, ribs, shoulder, hock, belly, loin and tongue. Whilst Chembensofu et al. (2017) found *T. solium* cysts in the liver and lungs during dissection, no cysts were found in any of these viscera in this study. Although the dissection slices made during this study ranged between 3 and 5 mm, cognisance must be taken that cysts could be missed, especially in very low infection or when they are very small (Chembensofu et al., 2017). Carcass dissection is not feasible as a routine method for detection of cysts because of the total destruction of a valuable commercial commodity and time constraints. Lightowlers et al. (2015) reported that dissecting the heart, tongue and masticatory muscles could be an alternative to full dissection as it gives a sensitivity of approximately 80%, including correct diagnosis in many lightly infected animals.

Ag-ELISA (B158/B60) showed a higher prevalence of *T. solium* (21.1%: 38/180) than carcass dissection (18.9%: 34/180) (Table 2) and our results are similar to other studies (Dorny et al., 2004; Chembensofu et al., 2017). Cases of positive Ag ELISA, but negative on carcass dissection, could be due to low numbers or small cysts missed at dissection, or it could be potential false positive. Ag-ELISA results highlighted that cross reactivity with metacestode stage of *T. hydatigena* should be taken into consideration when using Ag-ELISA (B158/B60). The low number of pigs with *T. hydatigena* cysts supports the statement by Dorny et al. (2004) that the parasite is not common in pigs in Africa. The use of Ag-ELISA testing on a routine basis in abattoirs is neither practical nor economically viable, especially in rural abattoirs that are far from the main national or provincial laboratories that can perform Ag-ELISA testing.

Considering the two district municipalities are adjacent to each

other, it was interesting to note that except for times when crops were being planted and pigs were deliberately penned or tied to prevent them entering the crop fields, most OR Tambo district pig owners allowed pigs to roam freely compared to those in the Alfred Nzo district.

5. Conclusion

As expected, the study demonstrated the ineffectiveness of detecting infected pigs during routine meat inspection at abattoirs. Therefore, additional or alternative methods of dissecting the heart, tongue and masticatory muscles to improve on sensitivity of meat inspection is required (Lightowlers et al., 2015). As an alternative to Lightowlers et al. (2015) in order to suit South African situation, our immediate suggestions is to make multiple incisions on the heart, tongue, shank and masticatory muscles.

In addition to the above suggested modifications to meat inspection, we suggest a holistic supply chain and risk-based meat safety assurance system be followed as complementary. There are a variety of food safety management systems, such as ISO 22000 (Escanciano and Santos-Vijande, 2014) and FSSC 22000 (Street, 2015); these promote a risk-based approach and follow a step-by-step process, Hazard Analysis of Critical Points (HACCP), which can be applied throughout the food chain.

The findings of this study compel relevant authorities to rethink current legislation. New methods that can be routinely used should be developed (Blagojevic et al., 2017). Legislation should provide for and encourage the establishment, implementation and maintenance of internationally recognised risk-based meat control systems as established by the Codex Alimentarius Commission (Havelaar et al., 2015), be flexible and open to scientific research, innovation, technology, epidemiological information and alternative documented approaches should be allowed, appreciated and exploited (Alvseike et al., 2018).

Ethical approval

This study was approved by the Faculty Committees for Research Ethics (FCRE) for human participation and Animal Research Ethics Committee (AREC) for the use of animals of the Tshwane University of Technology.

Conflict of interest

The authors declare they have no financial or personal interest that may have inappropriate influence in writing this article.

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