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Abstract

Cysticercosis caused by *Taenia solium* metacestode, is one of the major public health disease. Infected pigs play an important role in human taeniosis and cysticercosis. Recently much progress has been made towards immunodiagnosis of *T. solium* metacestode infection in pigs that have improved diagnostic sensitivity and specificity at field level. DNA approaches are now being used for accurate species specific identification of *Taenia* spp. Recent advances in diagnosis of porcine cysticercosis both antemortem and postmortem diagnostic techniques are reviewed in this article.

Key Words: *Taenia Solium* Metacestode; Serodiagnosis; Molecular Diagnosis; Pigs

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Introduction

Cysticercosis, caused by metacestode of *Taenia solium* is primarily an infection of pigs that acts as an intermediate host of *T. solium* and is a neglected disease [1] and an under rated zoonotic disease classified in list B by the OIE. Pigs become infected by the ingestion of eggs of *T. solium* during scavenging that are present in the stools of human beings who are the definitive host of *T. solium*. Earlier the larval stage or metacestode of *T. solium* was known as *Cysticercus cellulosae*, now the name is nowhere in use and is referred as metacestode or larval stage of *T. solium*. The larval stages (metacestodes) of *T. solium* form distinctive pearly-white cysts (cysticerci) and infection in man and pig is called cysticercosis. It is the leading cause of epilepsy in human population of the developing countries due to neurocysticercosis [2]. Now the disease is considered as emerging and reemerging parasitic disease [3]. Pigs can become infected at any age. Piglets become infected around the age of 2- 4 weeks and predominately during dry season. The metacestodes were found in the liver of piglets of 2 months of age and in older animals aged 4 to 6 months, the larvae were also found in the muscles. In a 6-month-old pig, larvae were found in the muscle and brain [4]. Breeders have a significantly higher prevalence

than weaners. Similarly fatteners had a significantly higher prevalence than weaned pigs [5]. Contrarily some studies show no relation between age and prevalence of infection [6-8].

Cysticercosis affects food security in pigs threatening human health, as pig will always be one of the major sources of food for mankind but is rarely associated with high mortality in intended host. Swine infected with *T. solium* metacestodes play a fundamental role in the transmission and maintenance of human taeniosis and cysticercosis with the consequent need for effective services of animal health and inspection of products of animal origin. Approximately 2.5 million people worldwide carry *T. solium* tapeworm and not less than 20 million people are infected with *T. solium* metacestode and 50,000 die of neurocysticercosis annually [9].

Porcine cysticercosis has even emerged as an important constraint for the nutritional and economic well being of smallholder farming communities due to down grading or total condemnation of affected meat in endemic area. About 68 per cent of hogs were condemned due to cysticercosis in Central America from 1959 to 1961 [10]. The estimate in Mexico for the cost of losses of pig production in 1980 was estimated as US \$ 43 million [11]. The annual losses in 10 West and Central African countries were 25 million Euros [12] and US \$ 121 million in China [13]. In India, the economic loss due to total carcass condemnation was reported as Rs. 64,600/- from Aligarh, Uttar Pradesh [6] and Rs. 2, 61,661 from Andhra Pradesh, which constituted 4.22 per cent of the overall cost of the pigs [14]. Protection of human health against zoonoses is mandatory by effective control of the disease for which the epidemiological data should be collected for improved monitoring arrangement. The identification of high prevalence zones, reliable sensitive and specific field applicable inexpensive procedures for its early and accurate detection is the need of the hour. Different techniques being followed for detection of *T. solium* metacestode infection in pigs including recent approaches are discussed in the following sections.

Diagnosis

In the recent past much progress has been made in research on diagnosis, treatment and prevention of human taeniosis and porcine cysticercosis, although more operational research is still

needed. In spite of this, global eradication of *T. solium* infection is still unlikely in the near future [15]. The lack of hygiene in the rural communities, free roaming of pigs, lack of education of pig owners, lack of control in the trade of pigs and their meat and lack of conscientious meat inspection has a direct bearing on the presence of adult worm in human [7,16-21]. Diagnosis of porcine cysticercosis is primarily of two types; one is antemortem inspection by tongue examination, clinical signs and serological studies, the second being the post mortem inspection.

Antemortem diagnosis

The antemortem diagnosis, based on clinical signs is usually not possible because clinical symptoms are not well defined in pigs. Clinical manifestation is noticeable only when the cysticerci get lodged in the eye or brain of pig when nervous symptoms are exhibited [22]. The cysticerci in brain are the main cause of late-onset epilepsy in human in tropical countries [2]. In contrast to their much studied effects upon human health, the impact of intracranial cysticerci upon pig health has not been fully explored and the information on clinical signs in infected pigs is scanty. Excessive salivation, blinking and lachrymation and in some cases sub-conjunctival nodules were the only reported signs [22,23]. Pigs that had many larvae in the brain appeared quieter and lay down for longer period than the other [20], some pigs however exhibited no apparent signs [24,25]. Gross and histopathological studies of brains of pigs revealed wide variation (3% to 60%) in NCC prevalence [22,26]. Proton magnetic resonance spectroscopy using creatin as a marker is valuable in prediction of viability of porcine neurocysticercosis [27].

The current method for detecting infected pigs in the field is tongue inspection. In tongue inspection, the pigs are considered positive for infection if cyst-like nodules are either seen or felt on palpation [28]. In vivo examination of tongue shows high specificity although its sensitivity is low, which is not always desirable [20,28,29], but several studies used palpable lingual cysts as indicator to estimate the prevalence of porcine cysticercosis and to study the potential risk factors associated with porcine cysticercosis [30].

Immuno diagnosis

Reliable antemortem serological test based on detection of specific antibody and antigen proves very useful in confirmatory diagnosis.

Immune responses

In infected animals the level of the serum antigen and antibody varies with the intensity of the infection. In heavily infected pigs, both antigen and antibodies can be detected at least 29 days and up to 200 days post infection (pi), while in lightly infected pigs antigen and antibodies are first observed between 61-97 days pi [31]. Immunity due to primary infection lasts at least 5 months. At 2 months of infection in piglets experimentally infected with eggs of *T. solium*, antigens of 24 and 39-42 kDa are most frequently recognized. In pigs with only a few caseous cysts in muscles and/or vesicular cysts in brains no antibodies could be detected [32]. The animals with viable cysts at necropsy have high antigen levels, whereas animals with no cysts or only degenerated cysts have low or no antigen levels and the trend is that the number of viable cysts decreases with the age at which the animals are infected [33]. An intense humoral response is observed in piglets experimen-

tally infected with *T. solium* eggs, from 10-30 days pi, and persisted up to 90-140 days [34-35] but cellular responses occur (increase in CD4 + T cells) at 60 days pi [36]. Interpretation of seropositive cases in piglets might be complicated by the maternal antibodies transferred from colostrum from a positive sow to its piglets which persists for 7 months, which has to be considered while studying the prevalence of cysticercosis in pigs [37].

T. solium metacestode antigens

Type of antigen used is mainly responsible for the sensitivity and specificity of cysticercosis diagnosis. So far crude and purified whole cyst antigen (WCA), cyst fluid antigen (CF), scolex and its fractionated antigens (SA), membrane antigens (MA), antigen B, excretory and secretory products of metacestode (E/S) of *T. solium*, were used with different sensitivity and specificity in different diagnostic methods. CFA are more sensitive than other components of *T. solium* metacestode as they are enriched with sensitive diagnostic glycoproteins [38-39] where as excretory-secretory antigens (E/S) are more specific than sensitive [40-41]. Use of Antigen B is limited in differential diagnosis of *T. solium* and *T. hydatigena* as it is also found in adult and larva of *T. hydatigena* [42].

Crude somatic antigens from *T. solium* metacestode revealed a protein band pattern ranging between 8 kDa and 200 kDa. Four poly peptides 8, 11, 16 and 23 kDa were specially recognized by pigs with confirmed cysticercosis [43]. Later, purification of glycoproteins and production of recombinant antigens was achieved to improve the performance of serology. 26kDa and /or 8 kDa antigens in crude saline extract of *T. solium* metacestodes were compared by immunoblot with Gp 13-50 antigens in a lentillectin semipurified glycoprotein extract of *T. solium* for antibody recognition. The seroprevalence represented a non significant difference with both antigens [16]. HP10 epitope-bearing antigens have been demonstrated in *T. solium* and *T. crassiceps* cyst fluid antigen and excretion/secretions for detection of antigens and antibodies in infected pigs [31]. The fractionated first peak of fluid antigen showed highest sensitivity and specificity followed by scolex and membrane antigens of *T. solium* in ELISA in naturally infected pigs [38]. Glycoproteins (GPs) purified by a single step iso-electric focusing electrophoresis (IEFE) [44-45] and recombinant chimeric antigen (RecTs) of *T. solium* [45] are good candidates for antibody detection in porcine cysticercosis. Analysis of *T. solium* metacestode cyst fluid by high performance liquid chromatography (HPLC) revealed 14 kDa fraction (F3) which showed high performance in Ab-ELISA with serum samples of pigs experimentally infected with *T. solium* eggs but when applied on field samples the performances of the F3-ELISA were lower than those of a crude cyst fluid antigen [46]. Both GPs and RecTs (African American, or Asian) are suitable for serological monitoring in infected pigs worldwide as they showed a correlation higher than 92% in serological tests. Comparison of native GPs with RecTs by ELISA demonstrated no statistical difference in sensitivity [47]. The use of TS-14 recombinant antigen in ELISA test (Ab-ELISA) can be useful for the diagnosis of cysticercosis in pigs with low infection [48].

Crude antigens of *T. solium* metacestode serologically cross react with other helminth parasites of pig [39,43,46,49]. Immunoperoxidase and indirect immunofluorescence studies showed distribution of cross reacting antigens mainly on the tegument of *T. solium* metacestode [50]. No cross reactions were observed with serum samples from pigs infected with other parasites using the HPLC purified fraction (F3) of cyst fluid [46]. Though purifica-

tion of antigen improves the test performance in terms of sensitivity and specificity, it requires large quantity of antigen and use of laborious and expensive procedures for specific antigen purification. Use of multiple antigens which are isolated and purified from closely related species (*Taenia crassiceps*) show cross reaction with *T. solium*. Hence, a crude metacestode antigen of *T. crassiceps* was used for detection of antibodies in cysticercosis infected pigs [51,29]. Sensitivity was high with cyst fluid and crude antigens of *T. crassiceps* compared to that of *T. solium* metacestode in diagnosis of porcine cysticercosis [52,53].

Antibody detection methods

Several immunoglobulin classes are produced as specific antibodies against the parasite i.e. IgG, IgM and little of IgA. The most frequent and persistent is IgG.

Conglutinating complement absorption test (CCAT): This is superior to CFT, IHA and BFT. Titer of antibody 1:80 and above is considered as positive in naturally infected pigs [54].

Indirect fluorescent antibody test (IFAT): Sensitivity is high with eggs of *T. solium* antigen and specificity was high with first peak of scolex antigen without any cross reaction with *C. tenuicollis* infected animal [55]. Practical utility is limited due to the requirement of special equipment.

Intradermal test (ID): It is simple, practical and sensitive method. Increase in thickness > 1.75 cm after 30 min is considered as positive [56]. Reaction completely disappears 48 hrs after inoculation. False negative and false positive reactions are observed at inoculation site [56-57].

Double immunodiffusion test (DID): Circulating antibodies could be detected in experimentally and naturally cysticercosis infected pigs [58]. DD test is time consuming and lack sensitivity [57].

Indirect haemagglutination test (IHA): False positive reactions and cross reactions with the serum of pigs infected with other helminth parasites occurs. This test is highly sensitive but less specific [57-58]. Though HA test lack repeatability and accuracy is still extensively used because of its high sensitivity and ease of application.

Counter immunoelectrophoresis (CIEP): Test is more rapid, simple and less expensive compare to other tests [59] and is more sensitive and specific than DID [58]. Sensitivity and specificity was 84.5 to 86.6 and 88.5 to 94.2 per cent with scolex and its fractionated antigens in diagnosis of porcine cysticercosis and could be used as field test in antemortem diagnosis [58,60]. Highest cysticercosis positive cases were detected in infected pigs by CIEP than in ELISA [61].

Latex agglutination test (LAT): In LAT, antigens /antibodies are combined to latex as a particle vector and the reactions between antigen and their specific antibodies are visualized as agglutination. LAT was as efficient as ELISA when antigen B was used [62].

Enzyme linked immunosorbent assay (ELISA): Till today ELISA is universally and extensively accepted technique for detection of antibodies because of its high sensitivity and specificity,

depending on the type of antigens used [29,39,46,52,58,61,63-64]. Several methods based on ELISA are established, including Dot-ELISA, gel ELISA [65] and Protein-A ELISA [66] which are of higher sensitive and specific and more convenient than ELISA.

Enzyme linked immunotransfer blot (EITB): Over the past decade EITB has been widely used for diagnosis of cysticercosis in pig serum samples [67]. It is highly sensitive (90-97.5%) and specific (100%) test than ELISA for antibody detection in pigs [28,42,67-70]. Though, many workers reported higher sensitivity of EITB than ELISA in the diagnosis of porcine cysticercosis, in developing countries, ELISA is preferred because of its better availability, simplicity and lower cost compared with immunoblot [71]. However, the sensitivity and specificity of ELISA was as par to those of the immunoblot [13]. ELISA was more sensitive than immunoblot when evaluated with RecTs of *T. solium* and reliable for differentiation of pigs infected with larvae of *T. solium* and those either uninfected or infected with other *Taeniid* species [45].

Antigen detection methods

It is difficult to determine cysticercosis positive pigs only by antibody detection methods because antibodies might continue to be present even after cure. The specific antibodies can be detected only after 1 week of post infection and reach the peak after 6-7 weeks [34-35] where as circulating antigens exist very early and will disappear as soon as parasite is killed. So, infected animals can be detected at the early stage of infection from the level of larval circulating antigens. Identification of infected pigs with viable larvae is achieved through detection of their secretory and excretory products using a monoclonal antibody-based capture assay [7,31,72-73]. Sensitivity and specificity of Ag-ELISA (86.7% and 94.7%) is more than Ab-ELISA (35.8% and 91.7%) in estimating the prevalence of porcine cysticercosis [29]. B158/B60 Ag-ELISA and HP10 Ag-ELISA are used to detect antigen-positive pigs and to understand the level of disease transmission [64,74-75] which was more sensitive than EITB [74]. Use of MoAb-TS14 for the detection of circulating antigen (Ag-ELISA) was not appropriate for pigs with low infection but, the test was successful for naturally heavily infected pigs [48].

Serological methods are more sensitive than tongue palpation for the detection of porcine cysticercosis [28], but several tongue positive pigs could not be confirmed by EITB [76] and Ag-ELISA [7]. Whereas, few authors [77] were able to detect pigs harboring even single cyst using Ag-ELISA. Differences in the sensitivity of the test may be related to the permeability of the host capsule around the metacestode that influences the amount of excretory-secretory products released into the circulation [78].

Immunogold techniques

The sensitivity of the currently available diagnostic techniques (Ag – ELISA, Ab – ELISA assays, EITB and tongue inspection) is low in pigs with low levels of cyst burdens [5,31,79] and requires access to laboratory with proper instrumentation and trained personnel. In 2008, ASARECA developed a pen-side diagnostic kit for *T. solium* cysticercosis in pigs under a project titled “Diagnostic and control tools and strategies for *T. solium* cysticercosis”. The principle of assay is similar to lateral flow assay, is used for detection of circulating antigen in which antibody labeled colloidal gold is an indicator for development of visible line on device. Recently, flow through assay or dot immunobinding assay is used at field level, in which colloidal gold is used as marker for detection

of antibodies especially for large scale screening of pigs against cysticercosis [39]. This test is user friendly, very simple, can be completed within 3 minutes without any equipment and is cost effective with visual results (colored dots in positive case).

Post Mortem Inspection

Meat inspection of pigs at slaughter is the only public health measure implemented to prevent *T. solium* transmission to humans, where inspected carcasses are detected at post mortem and subsequently downgraded or condemned [43,68]. In pigs, results of autopsy and enumeration of the cysts in the carcass considered as gold standard and provide a tool for validation of the immunodiagnostic tests [80]. Meat inspection is a major useful method when animals are heavily infected, but not when animals carry a few viable cysticerci [41,81]. Despite the efficacy of conventional inspection procedures, 40-50 per cent of the cases are not detected in mild infections [63]. The main drawback of routine meat inspection is its lack of sensitivity and objectivity as the procedure is restricted to certain predilection sites and is highly dependent on the expertise of the inspector as well as on the stage of cysts. Generalized infection of the carcass make it unfit for human consumption, however, lightly infected carcasses are not condemned but provided long term storage at low temperature at -10°C for 4 days greatly affect the value of the meat and hence the profit of owner.

Molecular techniques

Because of the lack of sensitivity and objectivity of meat inspection, an objective test to underpin the observation of meat inspector is needed. More over the degenerated metacestodes can be confounded with milk spots [82], hydatid cysts [83], *T. hydatigena* cysticerci, sarcocystis and piece of fat and left over of muscle fasciae. The identification of degenerated cysts also assumes importance for carcass judgment. Molecular diagnosis based on PCR test assumed significance due to its high specificity and sensitivity and can be used as simple presence / absence assay to detect the parasite of interest [84]. Consequently, PCR based techniques are being employed to study genetic variability, for species-specific identification of *Taeniid* spp. cysticerci and to validate meat inspection results in porcine cysticercosis [85-87], which is an appropriate postmortem test that could be applied on meat samples in suspected cases. Suspected lesion from the liver that resembled milk spot was also confirmed by PCR [87]. Milk spots in the liver of the pigs infected experimentally with *T. solium* eggs are confirmed by histology, ruling out *Ascaris* infection [82]. The performance of PCR and ELISA assays were compared for ante-mortem diagnosis of porcine cysticercosis, the ELISA assay showed high sensitivity and good specificity while the PCR assays showed high specificity but a low sensitivity [88]. Though, PCR based techniques are not difficult and have high sensitivity and specificity, demand expensive infrastructure and is not suitable as rapid on-site diagnostic test preventing the general use of this methods. Recently, proteomic analysis of *T. solium* metacestode excretion-secretion proteins was studied to improve the current diagnostic tools [89].

Conclusion

New and improved reliable diagnostic methods and strategies to identify infected pigs for the surveillance, prevention and control of this zoonotic disease are now available but cost and acces-

sibility remain drawback if these tests are to be used in endemic areas in developing countries. More attention should be given in improving antibody and antigen assays as user friendly by modifying them to be more practical and economical at field level e.g., dipsticks and lateral flow tests. Flow through assays like Malaria Kit in human, would greatly contribute to strengthen the control of metacestode of *T. solium* infection. The cysticercosis vaccines for pigs based on onchosphere antigens show great promise for blocking transmission to humans. Further research is required to ensure effective field application of the vaccines with regard to delivery and duration of protection.

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References

- Willingham ALIII, Harrison LJ, Fevre EM, Parkhouse ME (2008) Inaugural meeting of the cysticercosis working group in Europe. *EID J Home* 14(12).
- White AC (1997) Neurocysticercosis: a major cause of neurological disease worldwide. *Clinical Infect Dis* 24: 101-113.
- Craig PS, Pawlowski ZS (2002) *Cestode Zoonoses: Echinococcosis and Cysticercosis, an Emergent and Global problem*. NATO Science series, IOS Press. pp: 1-395.
- de Aluja AS, Martinez MJ, Villalobos AN (1998) Cysticercosis in young pigs: Age at first infection and histological characteristics. *Vet Parasitol* 76: 71-79.
- Boa ME, Mahundi EA, Kassuku AA, Willingham AL, Kyvsgaard NC (2006) Epidemiological survey of swine cysticercosis using antemortem and post-mortem examination tests in the southern highland of Tanzania. *Vet Parasitol* 139: 249-255.
- Pathak KML, Gaur SNS (1989) Prevalence and economic implications of *Taenia solium* taeniosis and cysticercosis in Uttar Pradesh State of India. *Acta Leidensia* 57: 197-200.
- Phiri IK, Dorny P, Gabriel S, Willingham AL, Speybroeck N, et al. (2002) The prevalence of porcine cysticercosis in Eastern and Southern provinces of Zambia. *Vet Parasitol* 108: 31-39.
- Joshi DD, Pandey KR, Dorny P, Bista PR, Verduyck J (2008) Comparison of carcass and lingual examination for the diagnosis of porcine cysticercosis in Nepal. *J Institute Med* 30: 11-17.
- Eddi C, Armando N, William A (2003) *Taenia solium* cysticercosis / taeniosis: Potential linkage with FAO activities; FAO support possibilities. *Acta Tropica* 87: 145-148.
- Garcia-Noval J, Sanchez AL, Allan JC (2002) In: Singh G, Prabhakar S (Eds) *Taenia solium* taeniosis and cysticercosis in Central America *Taenia solium* Cysticercosis: From Basic to Clinical Science. CABI Publishing, Wallingford, Oxon, UK, pp 91-100.
- Flisser A (1988) Neurocysticercosis in Mexico. *Parasitol Today* 4: 131-137.
- Zoli OA, Shey-Njila E, Assana JP, Nguemak P, Dorny J, et al. (2003) Regional Status, epidemiology and impact of *Taenia solium* cysticercosis in Western and Central Africa. *Acta Tropica* 87: 35-42.
- Ito A, Putr MI, Subahar R, Sato MO, Okamoto M, et al. (2002) Dogs as alternative intermediate hosts of *Taenia solium* in Papua (Irian Jaya), Indonesia confirmed by highly specific ELISA and immunoblot using native and recombinant antigens and mitochondrial DNA analysis. *J Helminthol* 76: 311-314.
- D'Souza PE, Hafeez Md 1998 Studies on *Cysticercus cellulosae* in pigs in an organized abattoir in Andhra Pradesh, India. *J Vet Parasitol* 12(1): 33-35.
- Pawlowski Z, Allan J, Sarti E (2005) Control of *Taenia solium* taeniosis/ cysticercosis: From research towards implementation. *Int J Parasitol* 35: 1221-1232.
- Rodriguez-Canul R, Allan JC, Dominguez LJ, Villegas S, Cob L, et al. (1998) Application of an immunoassay to determine risk factors associated with porcine cysticercosis in rural area of Yucatan, Mexico. *Vet Parasitol* 79(2): 165-180.
- Vazquez-Flores S, Ballesteros-Rodea G, Flisser A, Schantz PM (2001) Hygiene and restraint of pigs is associated with absence of *Taenia solium* cysticercosis in a rural community of Mexico. *Salud Publica Mex* 43: 574-576.
- Ngowi HA, Kassuku AA, Maeda GEM, Boa ME, Carabin H, et al. (2004) Risk factors for prevalence of porcine cysticercosis in Mbulu district, Tanzania. *Vet Parasitol* 120: 275-283.
- Sikasunge CS, Phiri IK, Phiri AM, Dorny P, Siziya S, et al. (2007) Risk factors associated with porcine cysticercosis in selected districts of Eastern and

- Southern provinces of Zambia. *Vet Parasitol* 143: 59-66.
- [20]. de Aluja AS (2008) Cysticercosis in the pig. *Current Topics Med Chem* 8: 368-374.
- [21]. Morales J, Martinez JJ, Rosetti M, Fieury A, Maza V, et al. (2008) Spatial distribution of *Taenia solium* porcine cysticercosis with in a rural area of Mexico. *PLOS Neglected Trop Dis* 2: 284.
- [22]. Prasad KN, Chawla S, Prasad A, Tripathi M, Husain N, et al. (2006) Clinical signs for identification of neurocysticercosis in swine naturally infected with *Taenia solium*. *Int J Parasitol* 55: 51-54.
- [23]. Kumar D, Gaur SNS (1994). *Taenia solium* cysticercosis in pigs. *Helminthological Abstracts, CAB International, UK*. 63: 365-383.
- [24]. Saenz B, Ramirez J, Aluja A, Escobar A, Frago G, et al. (2008) Human and porcine neurocysticercosis: differences in distribution and developmental stages of cysticerci. *Trop Med Int Health* 13: 695-702
- [25]. Sreedevi C, Ramadevi V, Anand Kumar P, Annapurna P (2011) Neurocysticercosis in a Pig. *Philipp J Vet Med* 48: 114-117.
- [26]. Prakash A, Sashikumar G, Rout M, Nagarajan K, Kumar R (2007) Neurocysticercosis in free roaming pigs-A slaughter house survey. *Trop Anim Health Prod* 39: 391-394.
- [27]. Chawla S, Gupta RK, Husain N, Garg M, Kumar R, et al. (2004) Prediction of viability of porcine neurocysticercosis with proton magnetic resonance spectroscopy: correlation with histopathology. *Life sciences* 74: 1081-92.
- [28]. Gonzalez AE, Cama V, Gliman RH, Tsang VCW, Plicher JB, et al. (1990) Prevalence and comparison of serologic assays, necropsy and tongue examination for the diagnosis of porcine cysticercosis in Peru. *Am J Trop Med Hygiene* 43: 194-199.
- [29]. Dorny P, Phiri IK, Vercruyse J, Gabriel S, Willingham IIIAL, et al. (2004) A Bayesian approach for estimating values for prevalence and diagnostic characteristics of porcine cysticercosis. *Int J Parasitol* 34: 569-576.
- [30]. Mutua FK, Randolph TF, Arimi SM, Kitale PM, Githigia SM, et al. (2007) Palpable lingual cysts, a possible indicator of porcine cysticercosis, in Teso District, Western Kenya. *J Swine Health Prod* 15(4): 206-212.
- [31]. Sciuotto E, Hernandez M, Garica G, Aluja ASde, Villalobos NM, et al. (1998) Diagnosis of porcine cysticercosis: a comparative study of serological tests for detection of circulating antibody and viable parasites. *Vet Parasitol* 78: 185-194.
- [32]. de Aluja AS, Villalobos ANM, Plancarte A, Rodarte LF, Hernandez M (1996) Experimental *Taenia solium* cysticercosis in pigs: characteristics of the infection and antibody response. *Vet Parasitol* 61: 49-59.
- [33]. Deckers N, Kanabona K, Silva M, Gonzalez AE, Garica HH, et al. (2008) Serological responses in porcine cysticercosis: A link with the parasitological outcome of infection. *Int J Parasitol* 38: 1191-1198.
- [34]. Grewall JS, Kaur S, Bhatti G, Ganguly NK, Mahajan RC, et al. (2000) Kinetics of humoral and cellular responses in experimental cysticercosis in pig infected with *Taenia solium*. *Indian J Med Res* 111: 43-49.
- [35]. Soares KA, Sliva MRM, Poleti MD, Maia AAM (2006) Immunodiagnosis of swine cysticercosis in swine experimentally infected with *Taenia solium* eggs, using antigens of *Cysticercus cellulosae* scolex. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia* 58: 15-20.
- [36]. Grewal JS, Kaur S, Bhatti G, Ganguly NK, Mahajan RC, et al. (2000) Kinetics of humoral and cellular immune responses in experimental cysticercosis in pigs infected with *T. solium*. *Indian J Med Res* 111: 43-49.
- [37]. Gonzalez AE, Verastegui M, Noh JC, Gavida C, Falcon N, et al. (1999) Persistence of passively transferred antibodies in porcine *Taenia solium* cysticercosis. The cysticercosis Working Group in Peru. *Vet Parasitol* 86: 113-118.
- [38]. Deka D, Gaur SNS (1993) Serodiagnosis of *Taenia solium* cysticercosis in naturally infected pigs by ELISA. *J Vet Parasitol* 7: 86 - 92.
- [39]. Sreedevi C, Hafeez Md, Subramanyam KV, Anand Kumar P, Chengalva Rayulu V (2011) Development and evaluation of flow through assay for detection of antibodies against porcine cysticercosis. *J Trop Biomed* 28: 160-170.
- [40]. Ng TF, Ko RC (1994) Serodiagnosis of Cysticercosis, specificity of different antigens and enzyme linked immunosorbent assays. *Trans Royal Society of Trop Med Hygiene* 88: 421-422.
- [41]. D'Souza PE, Hafeez Md (1999) An Enzyme linked immunosorbent assay in the detection of *Cysticercus cellulosae* infection in pigs. *J Vet Parasitol* 13: 125-127.
- [42]. Olivo A, Plancarte A, Flisser A (1988) Presence of antigen B from *Taenia solium* cysticercosis in other plathyhelminthes. *Int J Parasitol* 18: 543-545.
- [43]. Pathak KML, Allan JC, Ersfeld K, Craig PS (1994) A western blot and ELISA assay for the diagnosis of *Taenia solium* infection in pigs. *Vet Parasitol* 53: 209-217.
- [44]. Ito A, Plancarte A, Ma L, Kong Y, Flisser A, et al. (1998) Novel antigens for neurocysticercosis: Simple method for preparation and evaluation for serodiagnosis. *Am J Trop Med Hygiene* 59: 291-294.
- [45]. Sato MO, Yamasaki H, Sako Y, Nakao M, Nayaka K, et al. (2003) Evaluation of tongue inspection and serology for diagnosis of *Taenia solium* cysticercosis in swine: usefulness of ELISA using purified glycoproteins and recombinant antigens. *Vet Parasitol* 111: 309-332.
- [46]. Assana E, Kanobana K, Tume CB, Zoli PA, Nguetkam P, et al. (2007) Isolation of 14 kDa antigen from *Taenia solium* cyst fluid by HPLC and its evaluation in enzyme linked immunosorbent assay for diagnosis of porcine cysticercosis. *Res Vet Sci* 82: 370-376.
- [47]. Sato MO, Sako Y, Nakao M, Yamasaki H, Nakaya K, et al. (2006) Evaluation of purified *Taenia solium* glycoproteins and recombinant antigens in the serological detection of human and swine cysticercosis. *J Infect Dis* 194: 1783-1790.
- [48]. Silva MRM, Uyehara CNS, Silva FH, Espindola NM, Poleti MP, et al. (2012) Cysticercosis in experimentally and naturally infected pigs: Parasitological and immunological diagnosis. *Pesquisa Veterinária Brasileira* 32: 297-302.
- [49]. Ko RC, Ng TF (1998) Evaluation of excretory/secretory products of larval *Taenia solium* as diagnostic antigens for porcine and human cysticercosis. *J Helminthol* 72: 147-154.
- [50]. Cheng RWK, Ronald CKo (1991) Cross-reactions between crude antigens of larva (*Cysticercus cellulosae*) and other helminthes of pigs. *Vet Parasitol* 39: 161-170.
- [51]. Biondi GF, Mucciolo RG, Nunes CM, Richtzenhain IJ (1996) Immunodiagnosis of swine cysticercosis by indirect ELISA employing a heterologous antigen from *Taenia crassiceps* metacestode. *Vet Parasitol* 64: 261-266.
- [52]. Nunes CM, Biondi GF, Heinemann MB, Richtzenhain IJ (2000) Comparative evaluation of an indirect ELISA test for the diagnosis of swine cysticercosis employing antigens from *Taenia solium* and *Taenia crassiceps*. *Vet Parasitol* 93: 135-140.
- [53]. Pinto PSA, Vaz AAJ, Germano PML, Nakamura PM (2000) ELISA test for the diagnosis of cysticercosis in pigs using antigens of *Taenia solium* and *Taenia crassiceps* cysticerci. *Revista do Instituto de Medicina Tropical de São Paulo* 42: 71-79.
- [54]. Varma TK, Ahuvalia SS, Malviya HC (1984) Serodiagnosis of infection with *Cysticercus cellulosae* in pigs and *Taeniasis* in man and pups by conglutinating complement absorption test. *Indian J Com Microbiol Immunol Infect Dis* 5: 166-170.
- [55]. Kumar D, Gaur SNS, Varshney KC (1987) Indirect fluorescent antibody test in the diagnosis of porcine cysticercosis. *Indian J Anim Sci* 57: 1204-1206.
- [56]. Kumar D, Gaur SNS, Varshney KC, Pathak KML (1989) Intradermal test in the diagnosis of *Taenia solium* cysticercosis in pigs. *Indian J Anim Sci* 59: 500-505.
- [57]. Herbert IV, Oberg C (1975) Serological studies on pigs experimentally infected with *Taenia solium* or *Taenia hydatigena*. *J Com Pathol* 85: 487 - 498.
- [58]. Kumar D, Gaur SNS (1989) Comparative evaluation of various immunodiagnostic tests for the diagnosis of *Taenia solium* cysticercosis in pigs, using fractionated antigens. *J Helminthol* 63: 13 - 17.
- [59]. Pathak KML, Gaur SNS, Garg SK (1984) Counter current immunoelectrophoresis, a new technique for rapid serodiagnosis of porcine cysticercosis. *J Helminthol* 58: 321-324.
- [60]. Sharma R, Sharma DK, Juyal PD, Asha Rani, Sharma JK (2005) Comparative evaluation of counter immuno electrophoresis and routine meat inspection for the diagnosis of swine cysticercosis. *Indian J Anim Sci* 78: 792-793.
- [61]. D'Souza PE, Hafeez Md (1999) Comparison of routine meat inspection, CIEP and ELISA to detect *Cysticercus cellulosae* infection in pigs. *Indian Vet J* 76: 285-288.
- [62]. Prasanna KM, Jagannath MS, D'Souza PE (2001) Diagnosis of *Taenia solium* cysticercosis by latex agglutination test. *J Vet Parasitol* 15: 47-49.
- [63]. Pinto PSA, Almedia LP, Germano PML, Vaz AAJ, Nakamura PM (2002) Cysticercosis occurrence and sanitary risks in groups of infected and non-infected swine in Brazil. *Parasitologia latinoamericana* 57: 3-4.
- [64]. Cortez Alcobedes MM, Boggio G, Guerra Madel, Gavidia MRde, Rojas Reyes GC, et al. (2010) Evidence that active transmission of porcine cysticercosis occurs in Venezuela. *Trop Anim Health Prod* 42: 531-537.
- [65]. Wang RC, Wu CL, Zhang Y C, Ren ZB (1989) Detection of antibodies against *Cysticercus cellulosae* by diffusion in gel-ELISA. *J fourth Military Med University* 10: 309-311. (*Helminthol Abst* 1992, 61-547).
- [66]. Dhanalakshmi H, Jagannath MS, Isloor S, D'Souza PE (2006) Protein-A ELISA in the diagnosis of porcine cysticercosis. *J Vet Parasitol* 20: 30-35
- [67]. Tsang VCW, Joy A Pilcher, Wei Zhou, Anne E. Boyer, Ernest IP, et al. (1991) Efficacy of immunoblot assay for cysticercosis in pigs and modulated expression of distinct IgM/IgG activities to *Taenia solium* antigens in experimental infections. *Vet Immunol Immunopathol* 29: 69-78.
- [68]. Flisser A, Plancarte A, Correa D, Rodriguez Del-Rosal E, Feldman M, et al. (1990) New approaches in the diagnosis of *Taenia solium* cysticercosis and taeniosis. *Annals de parasitologie humaine et compare* 65: 95- 98 (*Helminthological Abstracts* 60: 3040).
- [69]. Sreenivasamurthy GS, D'Souza PE, Jagannath MS (1999) Enzyme linked immuno electro transfer blot in the diagnosis of *Taenia solium* cysticercosis in pigs. *J Parasitic Dis* 23: 85-88.
- [70]. Rodriguez-Hidalgo R, Benitez-Ortiz W, Praet N, Saa IR, Vercruyse J, et al. (2006) Taeniosis-cysticercosis in Southern Ecuador: assessment of infection status using multiple laboratory diagnostic tools. *Memrias do Instituto Oswaldo Cruz* 101: 779-782.
- [71]. Rosas N, Sotelo J, Nieto D (1986) ELISA in the diagnosis of neurocysticercosis. *Archives Neurol* 43: 57-58.

- [72]. Rodriguez-del-Rosal E, Correa D, Flisser A (1989) Swine Cysticercosis: detection of parasite products in serum. *Vet Record* 124: 488.
- [73]. Rodriguez-Hidalgo R, Benitez-Ortiz W, Dorny P, Geerts S, Geysen D, et al. (2003) Taeniosis-cysticercosis in man and animals in the sierra of Northern Ecuador. *Vet Parasitol* 118: 51-60.
- [74]. Krecek RC, Michael LM, Schantz PM, Ntanjana, Smith MF, et al. (2008) Prevalence of *Taenia solium* cysticercosis in swine from community based study in 21 villages of the Eastern Cape Provinces, South Africa. *Vet Parasitol* 154: 38-47.
- [75]. Waiswa C, Fevre EM, Nsadh Z, Sikasunge CS, Willingham ALIII (2009) Porcine cysticercosis in Southeast Uganda: Seroprevalence in Kamuli and Kaliro Districts. *J Parasitol Res* 9: 1-5.
- [76]. Diaz F, Garcia HH, Gilman RH, Gonzalez AE, Castro M, et al. The cysticercosis working group in Peru, (1992) Epidemiology of *Taeniasis* and cysticercosis in Peruvian village. *Am J Epidemiol* 135: 875-882.
- [77]. Nguekam, Zoli AP, Vondou L, Pouedet SMR, Assana E, et al. (2003) Kinetics of circulating antigens in pigs experimentally infected with *Taenia solium* eggs. *Vet Parasitol* 111: 323-332.
- [78]. Brandt JRA, Geerts S, De, De Deken RS, Kumae V, Ceulemans F, et al. (1992) A monoclonal antibody-based ELISA for the detection of circulating excretory-secretory antigens in *Taenia saginata* cysticercosis. *Int J Parasitol* 22: 471-477.
- [79]. Sciutto E, Martinez JJ, Villalobos NM, Hernandez M, Josh MV, et al. (1998) Limitations of current diagnostic procedures for the diagnosis of *Taenia solium* cysticercosis in rural pigs. *Vet Parasitol* 79: 299-313.
- [80]. Dorny P, Brandt J, Zoli A, Geerts S (2003) Immunodiagnostic tools for human and porcine cysticercosis. *Acta Tropica* 87: 79-86.
- [81]. Cai XP, Zheng YD, Luo XN, Jing ZZ, Hu M, et al. (2006) Immunodiagnosis of cysticercosis in China. *J Applied Res* 6: 69-76.
- [82]. de Aluja AS (1994) Manchas de leche (milk spots) por metacestodo de *Taenia solium* en hígados de cerdo. Milk spots (milk spots) by larvae of *Taenia solium* in pig livers. *Veterinaria Mexico* 25: 155-156 (in Spanish, with English abstract).
- [83]. Deplazes P, Grimm F, Sydler T, Tanner I, Kapel CMO (2005) Experimental alveolar echinococcosis in pigs, lesion development and serological follow up. *Vet Parasitol* 130: 213-222.
- [84]. Yamasaki H, Allan JC, Sato MO, Nakao M, Sako Y, et al. (2004) DNA differential diagnosis of taeniosis and cysticercosis by Multiplex PCR. *J Clinical Microbiol* 42: 548-553.
- [85]. Maravilla P, Souza V, Valera A, Romero-Valdivinos M, Lopez-Vidal Y, et al. (2003) Detection of genetic variation in *Taenia solium*. *J Parasitol* 89: 1250-4.
- [86]. Gonzalez AE, Villalobos N, Montero E, Morales J, Alamo Sanz R, et al. (2006) Differential molecular identification of *Taeniid* spp. and *Sarcocystis* spp. cysts isolated from infected pigs and cattle. *Vet Parasitol* 142: 95-101.
- [87]. Sreedevi C, Hafeez Md, Anand Kumar P, Chengalva Rayulu V, Subramanyam KV, et al. (2012) PCR test for detecting *Taenia solium* cysticercosis in pig carcasses. *Trop Anim Health Prod* 44: 95-99.
- [88]. Ramahefarisoa RM, Rakotondrazaka M, Jambou R, Carod JF (2010) Comparison of ELISA and PCR assays for the diagnosis of porcine cysticercosis. *Vet Parasitol* 173: 362-363.
- [89]. Victor B, Kanobana K, Gabriël S, Polman K, Deckers N, et al. (2012) Pro-

teomic analysis of *Taenia solium* metacestode excretion-secretion proteins.
Proteomics 12: 1860-9.