*International Journal of Bio-resource and Stress Management* https://pphouse.org/ijbsm.php

Crossref

*IJBSM April* 2022, 13(4):411-421 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR2690

**Research Article** *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2690

# Economic Implications of Porcine Cysticercosis Based on Meta-Analysis Estimates of its Prevalence in India

**Gajendra N. Bhangale**

Dept. of Veterinary Parasitology, College of Veterinary and Animal Sciences, Parbhani, MAFSU, Nagpur, VNMKV Campus, Parbhani, Maharashtra (431 402), India

Open Access

**Corresponding** gajumanu@gmail.com

0000-0001-8410-5333

## ABSTRACT

A meta-analysis of 27 studies systematically obtained from online free databases spanned over period from 2000 to 2019 from different parts of India was done. The pooled estimate of porcine cysticercosis prevalence using random effect model was found 5.21% with 95% CI as 4.04% to 6.52% and 95% PI 1.62%–15.46%. A wide variation in the prevalence estimates among studies under this analysis was observed which is confirmed through Q statistics =1322.38 (P=0.000). Substantial heterogeneity was observed between studies which is significant ($I^2$=96.52; $p$=<0.0001 and Tau squared value =0.0341) considering the diversity of populations reported in recruited studies. The sub-group analysis showed significantly higher prevalence in South region followed by North, North-east and West region of India. As regards the methods employed for detection of cysticerci from pigs, it was found that serological method showed higher rate of prevalence. A prevalence of 10.66% (95% CI=5.63% to 15.95%) is reported from those studies which used serological methods whereas carcass examination which is the frequently adopted method detected only 3.71% prevalence (95% CI =2.77% to 4.78%) and other methods such as molecular and histo-pathological studies for prevalence detected cysticercosis in 4.19% (95% CI=2.61% to 5.99%) carcasses over the study period under this meta-analysis. Considering its zoonotic significance as well as economic losses to pork industry, control strategies for PCC need to be devised with regards to health monitoring, hygienic meat practices coupled with education to both the producers and consumers through one health approach.

**KEYWORDS:** Cysticercosis, economic loss, hygiene, meta-analysis, taenia solium

***Citation* (VANCOUVER):** Bhangale, Economic Implications of Porcine Cysticercosis Based on Meta-Analysis Estimates of its Prevalence in India. *International Journal of Bio-resource and Stress Management*, 2022; 13(4), 411-421. HTTPS://DOI.ORG/10.23910/1.2022.2690.



***Data Availability Statement:*** Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

***Conflict of interests:*** The authors have declared that no conflict of interest exists.

RECEIVED on 27th October 2021 RECEIVED in revised form on 30th March 2022 ACCEPTED in final form on 24th April 2022 PUBLISHED on 30th April 2022

## 1. INTRODUCTION

Livestock parasitism constitutes one of major biotic stress factors in reducing the productivity of animals and deterioration of health (Radostits et al., 2000). Amongst them, zoonotic parasites has a distinct perspective as they exert risks both to livestock as well as human along with the state of persistent contamination of environment (Reinhard et al., 2013; Laranjo-Gonzalez et al., 2017). *Taenia solium* cysticercosis is known to be one of the most important parasitic zoonoses in tropical countries and porcine cysticercosis results in significant losses to pork industry worldwide (Rashid et al., 2018; Devleesschauwer et al., 2017). In human, the disease shows variable clinical entities if present in vital organs and remains sub-clinical if the cysts are present in striated muscles (Coral-Almeida et al., 2015, Mendlovic et al., 2021). Depending on the location, cysticercosis in human is manifested as ocular cysticercosis when eyes are involved or neurocysticercosis when nervous system is involved (Wardrop et al., 2016; Rajshekhar, 2016). The tapeworm is disseminated in the environment through pigs which are predominantly reared under scavenging type of management (Basanez et al., 2012). Due to lack of proper sanitation and un-hygienic conditions, human settlements in the proximity of such rearing systems are at higher risk of contracting the cysticercosis (Bizhani et al., 2020). In addition the lack of awareness coupled with unhygienic surroundings for a living make the populations at risk more prone to contracting such diseases (Kungu et al., 2017; Alarakol et al., 2021). The association between the prevalence of PCC with societies with poor sanitary conditions, inadequate hygiene, open defecation, presence of free roaming pigs and poverty have been reported through several earlier studies (Macpherson, 2005, Quet et al., 2010; Assana et al., 2012). With more prevalence in downtrodden societies, the impact of PCC is enormous (Ito et al., 2019).

Even after several control programs have been suggested and implemented in India, the situation in the country remain passive due to partial evidence based information about the extent of PCC to the stakeholders (Anonymous, 2013). The immunological control option though available in limited locations in India, its adoption in pigs is low and similar possibility in human seems obscure (Kabululu et al., 2020; Kaur et al., 2021). This warrants more information need to be generated with substantial accuracy as regards to the extent of PCC, validation of different detection methods as well as regarding awareness of common public on PCC apt practices (Wardrop et al., 2015).

Due to its zoonotic significance, as per the meat regulatory guidelines in most of the countries, the cysticercosis infected pork needs to be condemned and termed as unfit for human consumption (Girotra et al., 2014; Gabriel et al., 2015). Such meat condemnation although implies pork industry loss of a huge amount of revenue which would have added unless the safe pork is sold (Pathak and Chhabra, 2012). The economic impact of porcine cysticercosis due to the rejection of meat and edible offal has been reported throughout the globe (Rashid et al., 2018). In India, perhaps very few primary studies were attempted to estimate the losses suffered to pork industry due to porcine cysticercosis (Vaidya et al., 2014, Barua et al., 2019). The present study is an estimation of approximate losses to Indian meat industry due to porcine cysticercosis however it relies on data obtained from the meta-analysis of published prevalence reports.

## 2. MATERIALS AND METHODS

### *2.1. Meta-analysis*

The primary studies reporting the prevalence of porcine cysticercosis in pig carcasses and published between 2000 and 2019 obtained through systematic search of online free databases *viz.* GoogleScholar, PubMed, J-GatePlus were subjected to meta-analysis of its prevalence. PRISMA guidelines were followed for selection of studies for meta-analysis (Moher et al., 2009). Prevalence data from such selected studies were then systematically tabulated in Ms-Excel with respect to name of authors and year of publication, year of abattoir survey / sampling, place of work, method of detection, organs detected, number of carcasses/ animals detected and number of carcasses / samples found positive for harbouring *Taenia solium* cysts.

Meta-analysis was done to obtain pooled prevalence of PCC by employing random effects meta-analysis because of significant heterogeneity between studies for which Meta-XL addon is used as described in earlier studies (Bhangale, 2020). The effect size i.e. pooled prevalence and standard error of the effect size was calculated and then pooled with a 95% confidence interval. The between study variance was measured by Cochran's Q and Higgin's $I^2$ statistics. The heterogeneity was considered low, moderate and high if $I^2$ values were 25%, 50%, and 75% respectively (Higgins and Thompson, 2002). Funnel plot visualization and LFK Index was used for assessment of publication bias (Kanamori et al., 2018). Subgroup meta-analysis was also analyzed by grouping variables by regions of studies and methods of detection of cysts. All the analyses were done with the help of MetaXL add-in (EpiGear International Pty Ltd, Queensland, Australia).

### *2.2. Economic losses*

The economic loss accruing to organ condemnation and body weight loss due to cysticercosis was estimated on the basis of estimate given by Vaidya et al. (2014). The average economic loss reported in the study was calculated as ₹ 1726.31 per cysticercosis affected pig carcass which

was adjusted to the value of Rupees during in 2019 as per dynamics of Consumer price Index (RBI). Assuming that 50% of total pig population is slaughtered annually for meat purpose, total number of pigs slaughtered was calculated based on National Livestock Census report 2019 (DAHD, 2019). Consequently, number of cysticercosis infected pigs was then calculated by multiplying the pooled prevalence obtained through this meta-analysis with the total number of animals slaughtered in 2019.

## 3. RESULTS AND DISCUSSION

### *3.1. Characteristics of studies under meta-analysis*

Systematic search of the databases yielded 27 studies encompassing the prevalence of PCC from all over the country (Figure 1, Table 1). More number of studies were from Southern region (10) followed by Northern (09), North-eastern and Western region (04 each). Studies recruited showed that multiple methods were employed in same study for detection of cysts. Post mortem inspection (26 reports from 23 studies) was the most adopted method of detection of PCC while serological detection (18 reports from 07 studies) and molecular diagnosis were also followed for its detection. for post slaughter detection of PCC in pig carcasses shoulder muscle, thigh muscle, masseter muscle, neck, diaphragm and heart were most preferred sites while tongue, greater omentum, mesentery, other visceral organs including liver were also searched for presence of cysticerci. Serological detection was also found on rising trend of utility and adoption wherein ELISA, IFAT, CIEP, Western Blot were the preferred tests. One study revealed PCC prevalence

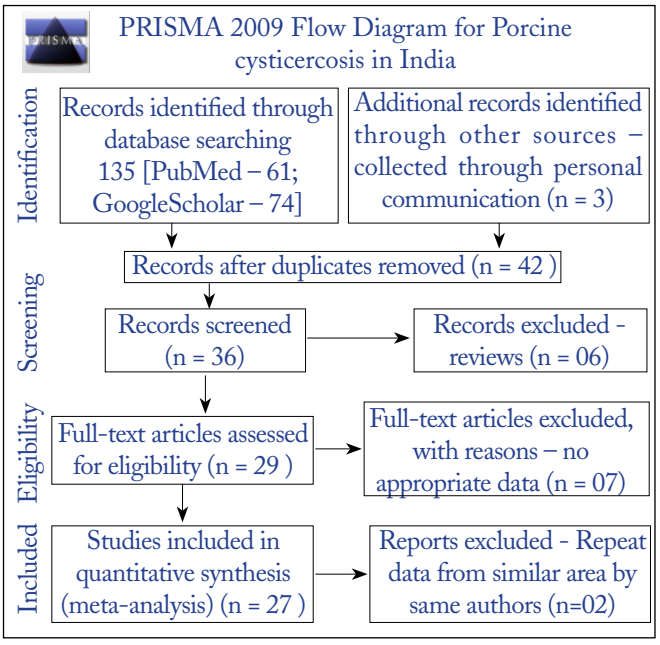


Figure 1: PRISMA 2009 Flow Diagram for Porcine cysticercosis in India, Moher et al. (2009). www.prisma-statement.org

by employing molecular diagnostic method while one other study reported prevalence from histo-pathological screening of pigs' brains.

### *3.2. Meta-analysis*

The pooled estimate of porcine cysticercosis prevalence using random effect model was found 5.21% with 95% CI as 4.04% to 6.52%. Proportion forest plot of pooled prevalence is presented in Figure 2. A wide variation in the prevalence estimates among studies under this analysis was observed which is confirmed through Q statistics =1322.38 with DF =29 and P=0.000. Substantial heterogeneity was observed between studies which is significant ($I^2$=96.52; p=<0.0001 and Tau squared value =0.0341) considering the diversity of populations reported in recruited studies.

Current review revealed pooled prevalence of porcine cysticercosis to the tune of 5.21% in pork samples/ pig carcasses. These results corroborate with Atawalna and Mensah (2015) from Ghana where they reported 4.59% prevalence of PCC in sows. Adesokan and Adeoye (2019) also reported 4.4% prevalence of PCC from Nigeria. Similarly, Rajshekhar (2004) in a review reported its prevalence in the range of 7–26% from India and 14–32% from Nepal. Mwabonimana et al. (2020) found porcine cysticercosis detected visually in 3.7% carcasses while with serological methods they detected PCC in 5.3% carcasses**.** Systematic review coupled with meta-analysis provide comprehensive overview on the dynamics of diseases or pathogens in a particular setup even if the outcomes may not be precise yet their applicability in planning surveillance and monitoring cannot be overlooked **(**Zammarchi et al., 2013; Laranjo-Gonzalez et al., 2017). None of the studies under the current meta-analysis reported organ wise prevalence. Yet it is established that lingual palpation is the best suited method for accurate diagnosis of cysticercosis in pig carcasses (Shonyela et al., 2018). As far as diagnostic approach with serological or molecular methods are concerned, it is not widely adopted evidenced by the reports under this meta-analysis.

### *3.3. Sub-group analysis*

The sub-group analysis of the prevalence of cysticercosis among pig in India has shown that more prevalence was noted in South (9.09% CI=6.08% to 12.40%) region followed by North (4.88% 95% CI=2.34% to 7.85%), North-east (3.67%, CI =1.54% to 6.22%) and West (2.46% CI=1.55% to 3.53%) which was significant (Table 2). As regards the methods employed for detection of cysticerci from pigs, it was found that serological method had shown precision in detecting the cysts in porcine hosts. Overall prevalence of 10.66% (95% CI=5.63% to 15.95%) is reported from those studies which used serological methods whereas carcass examination which most followed method detected

Table 1: Characteristics of the studies included in meta-analysis

| Study details | State | No. of carcass examined | Number of carcass with PCC | Prevalence (%) | Method of detection |
|---|---|---|---|---|---|
| Sarma et al., 2000 | Assam | 279 | 5 | 1.79 | Visual |
| Prasad et al., 2002 | Uttar Pradesh | 50 | 13 | 26.00 | Visual |
| Hafeez et al., 2004 | Andhra Pradesh | 935 | 33 | 3.52 | Visual |
| | Tamilnadu | 345 | 19 | 5.50 | Visual |
| | Karnataka | 366 | 21 | 5.73 | Visual |
| | Kerala | 167 | 9 | 5.38 | Visual |
| | Andhra Pradesh | 584 | 36 | 6.16 | CIEP |
| | Tamilnadu | 257 | 15 | 5.83 | CIEP |
| | Karnataka | 281 | 17 | 6.05 | CIEP |
| | Kerala | 123 | 7 | 5.69 | CIEP |
| | Andhra Pradesh | 584 | 38 | 6.50 | ELISA |
| | Tamilnadu | 257 | 16 | 6.22 | ELISA |
| | Karnataka | 281 | 18 | 6.40 | ELISA |
| | Kerala | 123 | 8 | 6.50 | ELISA |
| Selvam et al., 2004 | Karnataka | 507 | 21 | 4.14 | Visual |
| Sharma et al., 2005 | Punjab | 236 | 15 | 6.35 | Visual |
| Sharma et al., 2005 | Punjab | 236 | 34 | 14.40 | CIEP |
| Prakash et al., 2007 | Uttar Pradesh | 200 | 6 | 3.00 | Histopathology of brain |
| Borkataki et al., 2012 | Assam | 978 | 93 | 9.50 | Visual |
| Sreedevi et al., 2012 | Andhra Pradesh | 225 | 25 | 11.11 | Visual |
| Rout and Saikumar, 2012 | Uttar Pradesh | 119 | 4 | 3.36 | Visual |
| Kalai et al., 2012 | Maharashtra | 114 | 5 | 4.38 | Visual |
| Mohan et al., 2013 | Tamilnadu | 112 | 67 | 59.82 | ELISA |
| Bhadrige et al., 2014 | Maharashtra | 4042 | 23 | 0.56 | Visual |
| Koushik and Islam, 2014 | Assam | 316 | 4 | 1.26 | Visual |
| Saravanan et al., 2014 | Uttar Pradesh | 175 | 9 | 5.14 | Visual |
| Vaidya et al., 2014 | Maharashtra | 1820 | 18 | 0.98 | Visual |
| Chawhan et al., 2015 | Punjab | 519 | 22 | 4.23 | Visual |
| Sahoo et al., 2016 | Uttar Pradesh | 185 | 14 | 7.56 | Visual |
| Sreedevi et al., 2016 | Andhra Pradesh | 345 | 41 | 11.88 | Visual |
| Sharma et al., 2017 | J&K | 600 | 7 | 1.16 | Visual |
| Shende et al., 2016 | Maharashtra | 1735 | 6 | 0.34 | Visual |
| Abirami et al., 2018 | Tamilnadu | 175 | 46 | 26.28 | ELISA |
| Satyaprakash et al., 2018 | Maharashtra | 1000 | 3 | 0.30 | Visual |
| Singh et al., 2018 | Punjab | 1092 | 24 | 2.19 | Visual |
| Vaidya et al., 2018 | Maharashtra | 13596 | 120 | 0.88 | Visual |
| Barua et alv 2019a | Nagaland | 360 | 6 | 1.66 | Visual |
| Barua et al., 2019a | Nagaland | 300 | 9 | 3.00 | ELISA |

Table 1: Continue...

| Study details | State | No. of carcass examined | Number of carcass with PCC | Prevalence (%) | Method of detection |
|---|---|---|---|---|---|
| Barua et al., 2019b | Assam, Megha-laya, Aruna-chal Pradesh, Mizoram and Tripura | 4856 | 47 | 0.96 | Visual |
| Wavhal et al., 2019 | Maharashtra | 815 | 4 | 0.49 | Visual |
| | | 2228 | 20 | 0.89 | PCR |
| | | 524 | 34 | 6.48 | ELISA |
| | | 226 | 12 | 5.31 | FTA |
| | | 226 | 12 | 5.31 | Western Blot |
| | | 172 | 14 | 8.14 | ELISA |
| | | 172 | 13 | 7.55 | FTA |
| | | 172 | 12 | 6.97 | Western Blot |

Table 2: Subgroup analysis of studies on porcine cysticercosis in India

| | No of reports | Prevalence (%) | 95% C.I. | Q Statistics | $I^2$ (%) | p value | 95% P.I. |
|---|---|---|---|---|---|---|---|
| Sub-Group: Method of detection | | | | | | | |
| Carcass examination | 26 | 3.71 | 2.77–4.78 | 699.75 | 96.00 | 0.00 | 1.1–11.7 |
| Serology | 18 | 10.65 | 5.93–15.95 | 239.15 | 95.00 | 0.00 | 3.1–31.2 |
| Others | 3 | 4.18 | 2.61–5.99 | 1.44 | 0.00 | 0.49 | 0–90.0 |
| Sub-Group: Region | | | | | | | |
| East / NorthEast | 6 | 3.66 | 1.54–6.22 | 201.39 | 96.00 | 0.00 | 0.6–18.0 |
| North | 9 | 4.88 | 2.34–7.85 | 72.25 | 90.00 | 0.00 | 1.1–18.9 |
| South | 17 | 9.08 | 6.08–12.40 | 271.86 | 94.00 | 0.00 | 2.6–26.8 |
| West | 15 | 2.45 | 1.55–3.53 | 201.34 | 94.00 | 0.00 | 0.6–8.0 |
| Sub-Group: Sample size | | | | | | | |
| Less than 200 | 13 | 11.35 | 5.58–17.90 | 215.55 | 94.00 | 0.00 | 3.0–34.6 |
| 200-500 | 17 | 5.56 | 3.99–7.33 | 102.98 | 94.00 | 0.00 | 1.6–17.5 |
| 501-1000 | 10 | 3.65 | 1.66–6.03 | 219.06 | 96.00 | 0.00 | 0.8–14.3 |
| More than 1000 | 7 | 0.85 | 0.65–1.17 | 27.20 | 78.00 | 0.00 | 0.1–3.9 |

C.I.: Confidence Interval; P.I.: Prediction Interval

only 3.71% prevalence (95% CI=2.77% to 4.78%) and other methods such as molecular and histo-pathological studies for prevalence detected cysticercosis in 4.19% (95% CI=2.61% to 5.99%) carcasses over the study period under this meta-analysis.

The sub group analysis according to detection methods suggests that due to higher prevalence values in seroprevalence studies, overall pooled prevalence is higher which would not be actual prevalence as detected by direct detection of cysts through carcass examination or histo-pathological investigation. Yet their utility in ante-mortem screening followed by treatment must be encouraged for assuring the food safety standards (Phiri et al., 2006). In recent times the developments in imaging techniques such as ultrasonography may yield precision in the detection of cysticercosis (Flecker et al., 2017). The need of development of newer diagnostic approaches synergistically with immunological and molecular tools have been advocated by several studies mostly due to unsatisfactory reports on the part of specificity and sensitivity issues of existing methods (Jayashi et al., 2012, McKarthy et al., 2012; Goussanou et al., 2014).

Sub-group analysis according to the sample size of studies shows no major deviation in heterogeneity and indicates that as the sample size increases prevalence rates decreases. The studies under this meta-analysis mostly cover the urban or city areas where slaughtering is practiced under the aegis of regulations of municipal corporations (Prasad et al., 2008,

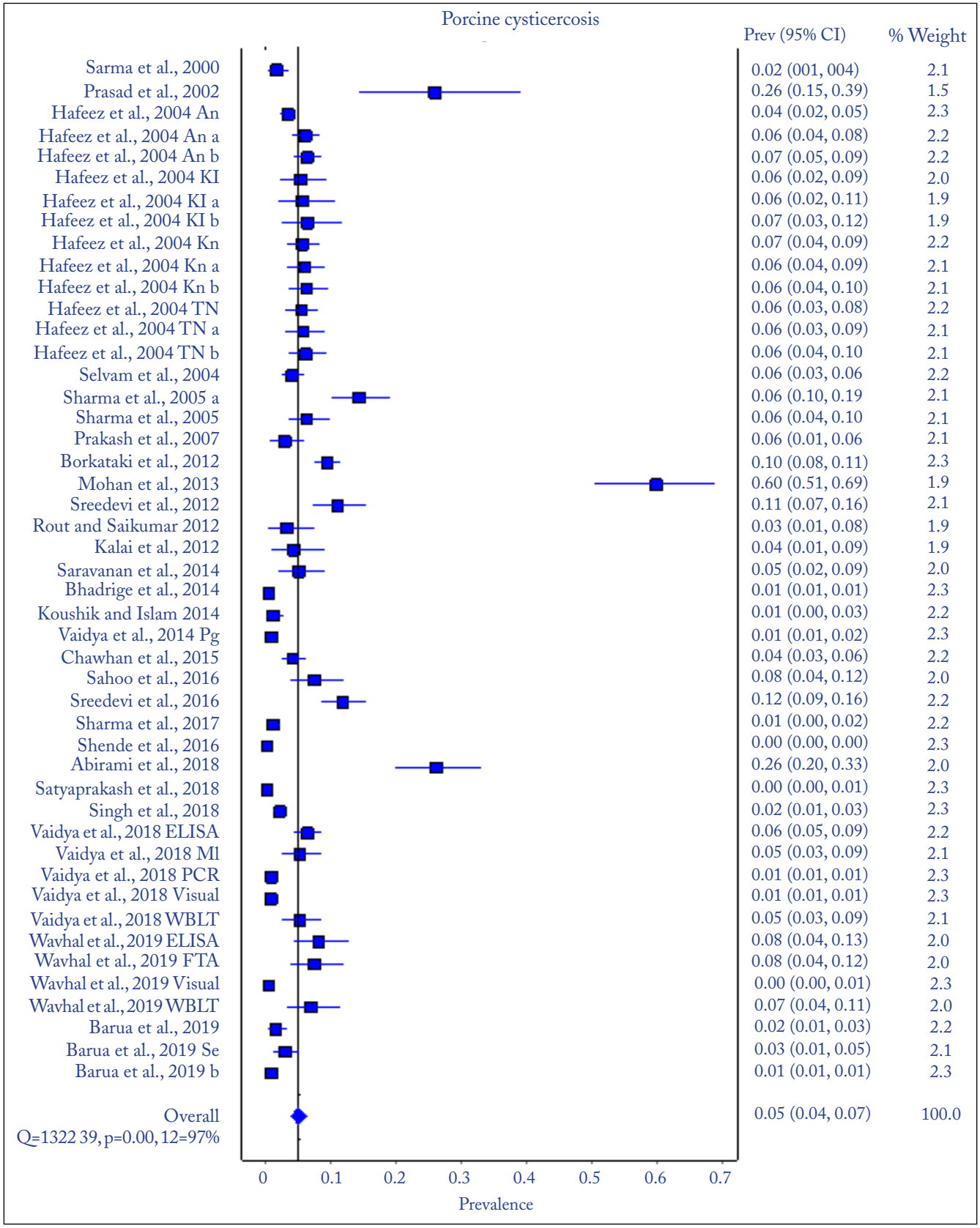


Figure 2: Forest plot of pooled prevalence of porcine cysticercosis in India

Barua et al., 2021). Yet the data on swine diseases including PCC from pigs slaughtered in rural settings has not been recorded or documented (Prasad et al., 2007, Haldar et al., 2017). This might reveal presence of the disease at relatively greater extent. The rationale for geographically uneven distribution of PCC may be attributed to the social and culinary preferences of various regions for swine husbandry in general and pork as a food in particular as compared to other regions of the country (Barua et al., 2021).

In India, pigs' husbandry in urban areas is mostly under scavenging system of rearing. Usually pigs are marked for identification and let free for roaming in town and city areas in open public places and sewage streams or tanks (Chouhan et al., 2016). Roaming of pigs around and proximity of slaughter facility to localities contribute significantly in risks of NCC in human (Assana et al., 2010, Akoko et al., 2019). Although no correlation reported between consumption of meat type and occurrence of NCC in human (Girotra et al., 2014).

### *3.4. Publication bias*

For publication bias assessment, the funnel plot was used and it showed presence of bias to the right side which could be attributed to more studies with relatively higher prevalence estimates. This was also supported by the Doi plot and LFK index (4.63) showing major asymmetry and thereby a substantial publication bias (Figure 3 and 4).

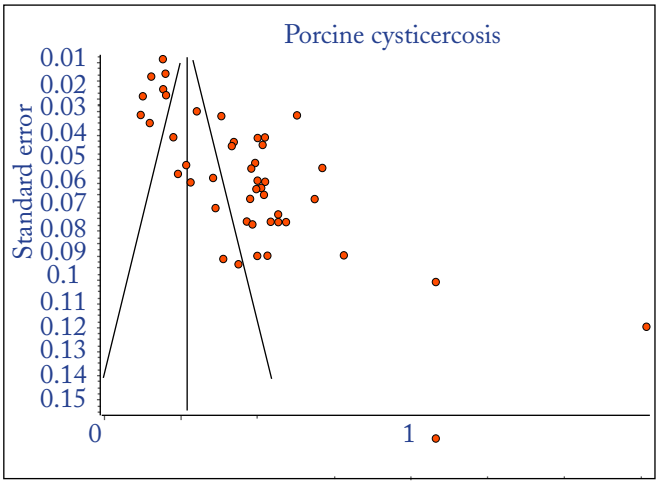


Figure 3: Funnel plot for publication bias in meta-analysis of porcine cysticercosis in India

### *3.5. Economics*

The projected economic cost of porcine cysticercosis attributed to the organ condemnation would be approximately INR 47,28,06,120/- for the calendar year 2019. The calculations and assumptions considered for this estimate are detailed in table 3.

As per standards set by food regulatory authorities in the country as well as abroad, it is mandatory to discard the PCC infected pork meat considering it unsuitable for human consumption. This usually incur significant cost to producers in terms of edible pork and/or offal being discarded which otherwise would have earned a monetary return. Very few studies have dealt with economic costs of parasitic diseases including cysticercosis in livestock. Earlier loss of ₹ 64600/- with a 3.8% prevalence was reported during year 1990 (Pathak and Gaur, 1990) from Uttar Pradesh whereas in southern India a loss of ₹ 2, 61, 661 was estimated due to 4.22% infection in an organized abattoir in Andhra Pradesh. (D' Souza and Hafeez, 1998). Recently Vaidya et al. (2014) approximated economic losses due to PCC to ₹ 1726.30/- per infected carcass in an

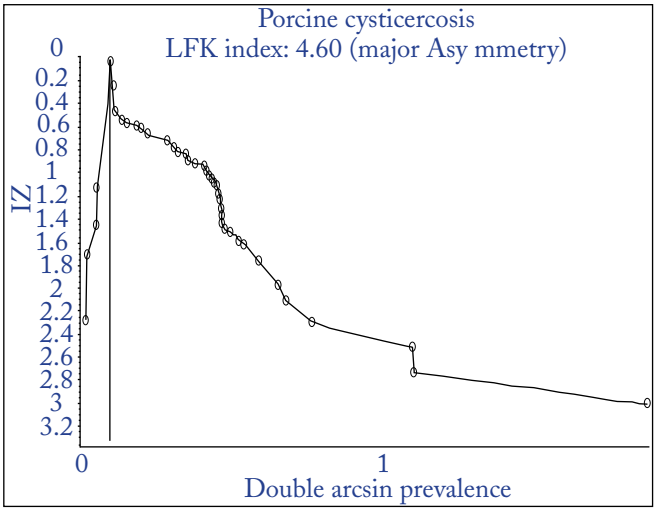


Figure 4: Doi plot for publication bias in meta-analysis of porcine cysticercosis in India

Table 3: Projected Economic costs of PCC on pork industry in India

| | |
|---|---|
| Total population of pig in 2019 census | 90,55,000 |
| Pigs slaughtered @50% assumption # | 45,27,500 |
| Prevalence of PCC by meta-analysis | 5.21 |
| Total number of pig infected with PCC | 2,35,890 |
| Per unit loss due to PCC in 2013-14 INR $ | 1726.31 |
| Approximate loss per infected carcass INR (adjusted by CPI @16.1058% rise over 2013-14*) | 2004.35 |
| Total economic loss due to organ condemnation in PCC | 472806121.50 |
| Total loss for calendar year 2019 INR | 47,28,06,120/- |

#: based on NAP by DAHD; $: Vaidya et al, 2014; *: Consumer Price Index from RBI; 1US$=?INR (avg. equivalent value for the average year of 2019)

abattoir based survey at Mumbai. This estimate was taken a baseline value for calculation of economic costs of PCC under current study. However this is first attempt to estimate the overall economic losses due to PCC at the country level which showed that approximately INR 47 crores are lost due to organ condemnation. It was also to be noted that these estimates are based only on the organ condemnation, however losses due to reduction in carcass weight are not dealt with in this study. In recent times, monetary losses associated with porcine cysticercosis were estimated at USD 19507171 in 2015 in Mexico, a South American country which considered the prevalence in the range of 0.05 to 0.33% in pigs slaughtered in various municipal abattoirs of the country (Bhattarai et al., 2019). Although the economic losses due to PCC may appear apprehensively lower as compared to the economic anatomy of the country to justify the steps to be taken for its control; its public health considerations undeniably needs significant attentions.

## 4. CONCLUSION

The prevalence of porcine cysticercosis in Indian pig is 5.21% and it has considerable bearing on the swine industry through meat condemnation and reduced production. Therefore special attention shall be given to concerted epidemiological monitoring of porcine cysticercosis and hygienic meat production and consumption practices should be popularized for its effective control. Diagnostics with enhanced specificity and sensitivity shall be developed for accurate surveillance in both human and pig hosts.

## 5. ACKNOWLEDGEMENT

The author expresses sincere gratitude to the authorities of College of Veterinary and Animal Sciences, Parbhani, MAFSU, Nagpur for providing the necessary facilities required for this research.

## 6. REFERENCES

Abirami, S., Sangaran, A., Sreekumar, C., Porteen, K., 2018. Evaluation of cysticercus cellulosae antigens for the diagnosis of cysticercosis in pigs by dot–ELISA. Journal of Veterinary Parasitology, 32, 42–44. http://dx.doi.org/10.5958/0974-0813.2018.00008.6.

Adesokan, H.K., Adeoye, F.A., 2019. Porcine cysticercosis in slaughtered pigs and factors related to *Taenia solium* transmission amongst abattoir workers in Ibadan, Nigeria. Pan African Medical Journal, 32, 1–13. https://doi.org/10.11604/pamj.2019.32.145.10695

Anonymous, 2013. Sustaining the drive to overcome the global impact of neglected tropical diseases: second WHO report on neglected diseases. Taeniasis/cysticercosis. Printed in France WHO/HTM/NTD/2013.1, 71–74.

Assana, E., Lightowlers, M.L., Zoli, A.P., Geerts, S., 2012. Taenia solium taeniosis/cysticercosis in Africa: Risk factors, epidemiology and prospects for control using vaccination. Veterinary Parasitology 195, 14–23. https://doi.org/10.1016/j.vetpar.2012.12.022.

Atawalna, J., Mensah, S., 2015. Prevalence and Financial losses associated with porcine cysticercosis in the kumasi metropolis of Ghana. International Journal of Livestock Research 5, 21–26. https://doi.org/10.5455/ijlr.20150825044155.

Barua, A., Raj, H., Goswami, C., Sonowal, D., Rajkhowa, U., 2018. Prevalence of porcine cysticercosis in four states of north East India. International Journal of Livestock Research 8(10), 212–218. https://doi.org/10.5455/ijlr.20171223071126.

Barua, A.G., Chutia, J.P., Nath, P.M., Raj, H., 2019. Procine cysticercosis : A neglected zoonoses and its economic impact in North East India. Indian Journal of Hill Farming 32, 231–235.

Barua, A.G., Sarma, M., Kakoty, Sharma, M., Kakoty, K., Rajkhowa, U., Nath, P.M., 2021. *Taenia solium* cysticercosis: present scenario: A review. Agricultural Reviews 42(2), 133–144. https://doi.org/10.18805/ag.R-1954.

Basanez, M.G., McCarthy, J.S., French, M.D., Yang, G.J., Walker, M., Gambhir, M., Prichard, R.K., Churcher, T.S., 2012. A research agenda for helminth diseases of humans: modelling for control and elimination. PLoS Neglected Tropical Diseases 6(4), e1548. https://doi.org/10.1371/journal.pntd.0001548.

Bhadrige, V.V, Zende, R.J., Paturkar, A.M., Vaidya, V.M., Deshmukh, A.V., 2014. Studies on prevalence of cysticercosis and its economic impact on cattle, buffalo and pig meat production. Journal of Veterinary Public Health 12, 19–23.

Bhangale, G., 2020. Gastrointestinal parasites in Indian buffaloes: a meta-analysis of prevalence. Journal of Veterinary Parasitolology 34(1), 41–50. https://doi.org/10.5958/0974-0813.2020.00002.9.

Bizhani, N., Hashemi Hafshejani, S., Mohammadi, N., Rezaei, M., Rokni, M.B., 2020. Human cysticercosis in Asia: A Systematic Review and Meta-Analysis. Iranian Journal of Public Health 49(10), 1839–1847. https://doi.org/10.18502/ijph.v49i10.4683.

Borkataki, S., Islam, S., Borkakati, M.R., Goswami, P., Deka, D.K., 2012. Prevalence of porcine cysticercosis in Nagaon, Morigaon and Karbianglong district of Assam, India. Veterinary World 5, 86–90. https://doi.org/10.5455/Vetworld.2012.86-90.

Braae, U.C., Hung, N.M., Satrija, F., 2018. Porcine cysticercosis (*Taenia solium* and *Taenia asiatica*):

mapping occurrence and areas potentially at risk in East and Southeast Asia. Parasites Vectors 11, 613. https://doi.org/10.1186/s13071-018-3203-z.

Chawhan, P., Singh, B.B., Sharma, R., Gill, J.P.S., 2015. Prevalence and molecular epidemiology of porcine cysticercosis in naturally infected pigs (*Sus scrofa*) in Punjab, India. OIE Revue Scientifique et Technique 34, 953–960. https://doi.org/10.20506/rst.34.3.2408.

Chembensofu, M., Mwape, K.E., Van Damme, I., 2017. Re-visiting the detection of porcine cysticercosis based on full carcass dissections of naturally *Taenia solium* infected pigs. *Parasites Vectors* 10, 572. https://doi.org/10.1186/s13071-017-2520-y.

Coral-Almeida, M., Gabriel, S., Abatih, E.N., Praet, N., Benitez, W., Dorny, P., 2015. Taenia solium human cysticercosis: A systematic review of sero-epidemological data from endemic zones around the world. PLoS Neglected Tropical Diseases 9, 1–20. https://doi.org/10.1371/journal.pntd.0003919.

D'Souza, P.E., Hafeez, M., 1998. Incidence of Cysticercus cellulosae infection in pigs in Andhra Pradesh. Mysore Journal of Agricultural Sciences 32, 75–78.

Devleesschauwer, B., Allepuz, A., Dermauw, V., Johansen, M.V., Laranjo-Gonzalez, M., Smit, G.S., 2017. *Taenia solium* in Europe: Still endemic? Acta Tropica, 165, 96–9. https://doi.org/10.1016/j.actatropica.2015.08.006.

Flecker, R.H., Pray, I.W., Santiva-ez, S.J., Ayvar, V., Gamboa, R., Muro, C., 2017. Assessing Ultrasonography as a Diagnostic tool for porcine cysticercosis. PLoS Neglected Tropical Diseases, 11(1): e0005282. https://doi.org/10.1371/journal.pntd.0005282.

Gabriel, S., Johansen, M.V., Pozio E., Smit, G.S., Devleesschauwer, B., Allepuz, A., 2015. Human migration and pig/pork import in the European Union: What are the implications for *Taenia solium* infections? Veterinary Parasitology 213(1–2), 38–45. https://doi.org/10.1016/j.vetpar.2015.03.006.

Girotra, M., Gera, C., Abraham, R.R., Kaur, P., Gauba, R., Singh, Y., Pandian, J.D., 2014. Risk factors for neurocysticercosis: A study from Northwest India. CHRISMED Journal of Health and Research, 1, 21.

Goussanou, J.S.E., Kpodekon, M.T., Youssao, A.K.I., Farougou, S., Korsak, N., 2014. Epidemiological tools for effective surveillance of porcine cysticercosis in Africa. Veterinary World 7, 125–134. https://doi.org/10.14202/vetworld.2014.125-134.

Hafeez, M., Reddy, C.V.S., Ramesh, B., Devi, D.A., Chandra, M.S., 2004. Prevalence of porcine cysticerosis in South India. Journal of Parasitic Diseases 28, 118–120.

Higgins, J.P.T., Thompson, S.G., 2002. Quantifying heterogeneity in a meta-analysis. Statistics in Medicine 21, 1539–1558. https://doi.org/10.1002/sim.1186.

Ito, A., Li, T., Wandra, T., Dekumyoy, P., Yanagida, T., Okamoto, M., Budke, C.M., 2019. Taeniasis and cysticercosis in Asia: a review with emphasis on molecular approaches and local lifestyles. Acta Tropica, 198, 105075 https://doi.org/10.1016/j.actatropica.2019.105075.

Jayashi, C.M., Arroyo, G., Lightowlers, M.W., Garcia, H.H., Rodriguez, S., Gonzalez, A.E., 2012. Seroprevalence and risk factors for Taenia solium cysticercosis in rural pigs of Northern Peru. PLoS Neglected Tropical Diseases 6, 1–5. https://doi.org/10.1371/journal.pntd.0001733.

Kabululu, M.L., Ngowi, H.A., Mlangwa, J.E.D., Mkupasi, E.M., Braae, U.C., Colston, A., 2020. TSOL18 vaccine and oxfendazole for control of *Taenia solium* cysticercosis in pigs: A field trial in endemic areas of Tanzania. PLoS Neglected Tropical Diseases, 14(10), e0008785. https://doi.org/10.1371/journal.pntd.0008785.

Kalai, K., Nehete, R.S., Ganguly, S., Ganguli, M., Dhanalakshmi, S., Mukhopadhayay, S.K., 2012. Investigation of parasitic and bacterial diseases in pigs with analysis of hematological and serum biochemical profile. Journal of Parasitic Diseases 36, 129–134. https://doi.org/10.1007/s12639-011-0068-x.

Kanamori, L.F., Barendregt, J.J., Doi, S.A.R., 2018. A new improved graphical and quantitative method for detecting bias in meta-analysis. International Journal of Evidence Based Healthcare 16, 195–203. https://doi.org/10.1097/xeb.0000000000000141.

Koushik, K., Islam, S., 2014. Prevalence of porcine cysticercosis in sivasagar district of Assam, India. Journal of Veterinary Parasitology 28, 164–165.

Kungu, J.M., Dione, M.M., Ejobi, F., 2017. Risk factors, perceptions and practices associated with *Taenia solium* cysticercosis and its control in the smallholder pig production systems in Uganda: a cross-sectional survey. BMC Infectious Diseases 17, 1. https://doi.org/10.1186/s12879-016-2122-x.

Laranjo-Gonzalez, M., Devleesschauwer, B., Trevisan, C., 2017. Epidemiology of taeniosis/cysticercosis in Europe, a systematic review: Western Europe. Parasites & Vectors 10, 349. https://doi.org/10.1186/s13071-017-2280-8.

Macpherson, C.N., 2005. Human behaviour and the epidemiology of parasitic zoonoses. International Journal for Parasitology 35(11), 1319–1131.

McCarthy, J.S., Lustigman, S., Yang, G.J., Barakat, R.M., Garcia, H.H., Sripa, B., 2012. A research agenda for

helminth diseases of humans: diagnostics for control and elimination programmes. PLoS Neglected Tropical Diseases 6(4), e1601.

Mendlovic, F., Fleury, A., Flisser, A., 2021. Zoonotic taenia infections with focus on cysticercosis due to taenia solium in swine and humans. Research in Veterinary Science 134, 69-77. https:// doi.org/https:// doi.org/10.1016/j.rvsc.2020.11.015.

Mohan, V.R., Tharmalingam, J., Muliyil, J., Oommen, A., Dorny, P., Vercruysse, J., Vedantam, R., 2013. Prevalence of porcine cysticercosis in Vellore, South India. Transactions of the Royal Society of Tropical Medicine and Hygiene 107, 62–64.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2009. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Journal of Clinical Epidemiology 62(2009), 1006–1012. https:// doi.org/10.1016/j.jclinepi.2009.06.005.

Mwabonimana, M., Macharia, A., Inyagwa, C.M., Shakala, K., Bebe, B.O., 2020. Prevalence of porcine cysticercosis among scavenging pigs in western Kenya. African Journal of Infectious Diseases 14, 30–35.

Pathak, K.M.L., Chhabra, M.B., 2012. Taenia solium cysticercosis in India: A vetero-medical update. Indian Journal of Animal Sciences 82, 937–945.

Pathak, K.M.M., Gaur, S.N., 1989. Prevalence and economic implications of Taenia solium taeniasis and cysticercosis in Uttar Pradesh State of India. Acta Leidensia 57(2), 197–200.

Prakash, A., Kumar, G.S., Rout, M., Nagarajan, K., Kumar, R., 2007. Neurocysticercosis in free roaming pigs - A slaughterhouse survey. Tropical Animal Health and Production 39, 391–394.

Prasad, K.N., Chawla, S., Jain, D., Pandey, C.M., Pap, L., Gupta, S., Pradhan, R.K., 2002. Human and porcine Taenia solium infection in rural north India. Transactions of the Royal Society of Tropical Medicine and Hygiene 96, 515–516.

Quet, F., Guerchet, M., Pion, S.D.S., Ngoungou, E.B., Nicoletti, A., Preux, P.M., 2010. Meta-analysis of the association between cysticercosis and epilepsy in Africa. Epilepsia 51, 830–837.

Radostits, O.M., Gay, C.C., Blood, D.C., Hinchkliff, K.W., 2000. Veterinary Medicine. 9th edition. ELBS, Bailliere Tindall, 1541–1564.

Rajshekhar, V., 2004. Epidemiology of taenia solium taeniasis/cysticercosis in India and Nepal. Southeast Asian Journal of Tropical Medicine and Public Health 35, 247–251.

Rajshekhar, V., 2016. Neurocysticercosis: Diagnostic problems & current therapeutic strategies. Indian Journal of Medical Research 144, 319–326.

Rashid, M., Rashid, M.I., Akbar, H., Ahmad, L., Hassan, M.A., Ashraf, K., Saeed, K., Gharbi, M., 2018. A systematic review on modelling approaches for economic losses studies caused by parasites and their associated diseases in cattle. Parasitology, 1–13. https://doi.org/10.1017/S0031182018001282.

Reinhard, K.J., Ferreira, L.F., Bouchet, F., Sianto, L., Dutra, J.M., 2013. Food, parasites, and epidemiological transitions: a broad perspective. International Journal of Paleopathology 30(3), 150–157.

Kaur, R., Arora, N., Rawat, S.S., Keshri, A.K., Sharma, S.R., Mishra, A., Singh, G., Prasad, A., 2021. Vaccine for a neglected tropical disease *Taenia solium* cysticercosis: fight for eradication against all odds, Expert Review of Vaccines 20(11), 1447–1458. https://doi.org/10.1 080/14760584.2021.1967750.

Rout, M., Saikumar, G., 2012. Porcine cysticercosis: An underestimated zoonotic disease. Indian Journal of Veterinary Pathology 36, 94–96.

Alarakol, S.P., Bagaya, B.S., Yagos, W.O., Odongo Aginya, E.I., 2021. Prevalence and risk factor associated with Taenia solium cysticercosis among pig farmers in two districts (Amuru and Gulu) in Northern Uganda. Journal of Parasitology and Vector Biology 13(1), 25–34, https://doi.org/10.5897/JPVB2020.0395.

Sahoo, M., Singh, R., Singh, K.P., Sharma, A.K., Saikumar, G., Sylvester, L., Ray, P.K., 2016. Prevalence and pathology of cysticercosis in slaughtered pigs of Rohilkhand region. Indian Journal of Veterinary Pathology 40, 69.

Saravanan, B.C., Manjunathachar, H.V., Tewari, A.K., Gupta, S.C., Karthik, K., Tamilmahan, P., Sudhakar, N.R., 2014. Prevalence of porcine cysticercosis in Bareilly, Northern India. Veterinary World 7, 281–283.

Sarma, M.D., Deka, D.K., Borkakati, M.R., 2000. Occurrence of hydatidosis and porcine cysticercosis in Guwahati city. Journal of Veterinary Parasitology 14, 173–174.

Satyaprakash, K., Khan, W.A., Chaudhari, S.P., Shinde, S.V., Kurkure, N.V., Kolte, S.W., 2018. Pathological and molecular identification of porcine cysticercosis in Maharashtra, India. Acta Parasitologica 63, 784–790.

Selvam, P., D'Souza, P.E., Jagannath, M.S., 2004. Serodiagnosis of taenia solium cysticercosis in pigs by indirect haemagglutination test. Veterinarski Arhiv 74, 453–458.

Sharma, R., Sharma, D., Juyal, P., Rani, A., Sharma, J., 2005. Seroprevalence of swine cysticercosis in Ludhiana. Journal of Veterinary Parasitology 19, 143–145.

Sharma, R., Sharma, H.K., Sharma, R., Katoch, R., Kaur,

R., Rashid, M., Ganai, A., 2017. Epidemiological study on prevalence of cysticercus cellulosae in pigs of Jammu region. Veterinary Practitioner 18, 102–105.

Shende, R.G., Vaidya, V.M., V., Zende, R.J., Paturkar, A.M., Waghmare, R.N., Kale, L.S., Bhave, S.S., 2016. Incidence of cysticercosis in pigs slaughtered at Deonar Abattoir, Mumbai. Journal of Bombay Veterinary College 23, 12–14.

Shonyela, S.M., Yang, G., Wang, C., 2018. Current status of prevalence, possible control and risk factors associated with porcine cysticercosis from endemic countries in Africa. World Journal of Vaccines 08, 53–80.

Singh, S.P., Singh, B.B., Kalambhe, D.G., Pathak, D., Aulakh, R.S., Dhand, N.K., 2018. Prevalence and distribution of Taenia solium cysticercosis in naturally infected pigs in Punjab, India. PLoS Neglected Tropical Diseases 12, 1–12.

Sreedevi, C., Hafeez, M., Kumar, P.A., Rayulu, V.C., Subramanyam, K.V., Sudhakar, K., 2012. PCR test for detecting Taenia solium cysticercosis in pig carcasses. Tropical Animal Health and Production 44, 95–99.

Sreedevi, C., Rama Devi, V., Annapurna, P., 2016. Prevalence of porcine cysticercosis in coastal districts of Andhra Pradesh: An abattoir survey. Journal of Veterinary Parasitology 30, 90–94.

Torgerson, P.R., 2013. One world health: socioeconomic burden and parasitic disease control priorities. Vet Parasitol 195(3–4), 223–232.

Vaidya, V., Paturkar, A., Zende, R., Gatne, M., Dighe, D., Waghmare, R., Moon, S., Bhave, S., Jadhav, P., Wavhal, N., 2018. Scenario of porcine cysticercosis and human taeniasis in Maharashtra State, India. Turkish Journal of Veterinary and Animal Sciences 42, 353–358.

Vaidya, V.M., Zende, R.J., Paturkar, A.M., Kumar, A., Raut, C.K., 2014. Economic impact of hydatidosis and cysticercosis in food animals slaughtered at different abattoirs of Maharashtra. Journal of Veterinary Public Health 12, 65–70.

Wardrop, N.A., Thomas, L.F., Atkinson, P.M., de Glanville, W.A., Cook, E.A.J., Wamae, C.N., Gabriel, S., Dorny, P., Harrison, L.J.S., Fevre, E.M., 2015. The influence of socio-economic, behavioural and environmental factors on *Taenia* spp. Transmission in Western Kenya: Evidence from a Cross-Sectional Survey in Humans and Pigs. PLoS Neglected Tropical Diseases 9, 1–16

Wavhal, N., Paturkar, A., Vaidya, V., Waghmare, R., Zende, R., Moon, S., 2019. Seroprevalence of porcine cysticercosis in Maharashtra. Indian Journal of Animal Sciences 89, 365–368.

Zammarchi, L., Strohmeyer, M., Bartalesi, F., Bruno, E., Munoz, J., Buonfrate, D., Epidemiology and management of cysticercosis and *Taenia solium* taeniasis in Europe, systematic review 1990–2011. PLoS One 8(7), e69537.