Journal of Helminthology

cambridge.org/jhl

Helminths of zoonotic importance in slaughtered food animals in Nigeria: a systematic review and meta-analysis

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Research Paper

Cite this article: Karshima SN (2019). Helminths of zoonotic importance in slaughtered food animals in Nigeria: a systematic review and meta-analysis. *Journal of Helminthology* **93**, 295–305. https://doi.org/10.1017/S0022149X18000196

Received: 11 January 2018
Accepted: 26 January 2018
First published online: 5 March 2018

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Abstract

Knowledge of endemic helminths in a resource-limited country such as Nigeria is essential for their diagnosis, treatment and cost-effective control. In the present study, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guideline was employed to determine the prevalence and geographical distribution of zoonotic helminths in food animals slaughtered in Nigerian abattoirs between 1970 and 2016. Pooled prevalence estimate (PPE) was determined by the random-effects model while heterogeneity was evaluated using the Cochran's *Q*-test. Results from 42 eligible studies reported across 19 Nigerian states revealed 85,466 cases of zoonotic helminths from 3,771,832 slaughtered food animals. Overall PPE was 2.27% (95% confidence interval (CI): 2.25, 2.28). PPEs for sub-groups ranged between 0.51% (95% CI: 0.46, 0.56) and 18.05% (95% CI: 17.12, 19.01) across regions, hosts, study periods and diagnostic methods. *Ascaris suum* had the highest pooled prevalence of 25.46% (95% CI: 24.04, 26.92). Overall prevalence estimates for cestodes, nematodes and trematodes were 0.60% (95% CI: 0.59, 0.61), 21.51% (95% CI: 20.73, 22.30) and 1.86% (95% CI: 1.84, 1.87), respectively. A high degree of heterogeneity 99.97% (95% CI: 2.25, 2.28, *P*: 0.000) was observed. Zoonotic helminths were prevalent in slaughtered food animals, with higher prevalence estimates in the north–central region, pigs and during the last decade reviewed. *Ascaris suum* was the most prevalent helminth, while *Fasciola gigantica* had the widest geographical distribution. It is envisaged that the present information will help in the formulation of disease-control policies, encourage on-farm good agricultural practices, and adequate hygiene and sanitation in abattoirs and meat-processing plants, with the aim of protecting public health.

Introduction

Helminth parasites transmissible between animals and humans under natural conditions are referred to as zoonotic helminths. They are generally classified into two phylogenetic groups: nematoda, which are commonly called roundworms (e.g. *Ascaris*, *Toxocara, Trichinella spiralis*), and platyhelminthes, which include cestodes (e.g. *Echinococcus* species, *Hymenolepis nana*, *Taenia* species) and trematodes (e.g. *Fasciola* species, *Gongylonema pulchrum* and *Eurytrema pancreaticum*). Infections are acquired principally through the consumption of contaminated pasture or tissues of infected animals, and direct skin penetration (Nejsum *et al*., 2005; Uysal *et al*., 2009).

Zoonotic helminths are associated with significant economic losses as a result of direct disease causation in humans and animals, which are manifested by sub-clinical, clinical infections and death. Indirect losses caused by these parasites are incurred through the cost of ensuring safety in the food chain (Torgerson, 2013; Devleesschauwer *et al*., 2014). Major public health problems associated with zoonotic helminths of food-animal origin globally may include ocular and neuro-cysticercosis caused by metacestodes of *Taenia solium,* which is incriminated in the majority of cases of epilepsy in Africa (Diop *et al*., 2003). Others are human hydatidoses, caused by members of the genus *Echinococcus*, as well as cutaneous, ocular and visceral larval migrans due to certain nematodes (Tamminga *et al*., 2009; González *et al*., 2015).

Substantive evidence has shown that zoonotic helminths are endemic in humans in Nigeria (Dada, 1980; Weka *et al*., 2013; Adedoja *et al*., 2015; Odinaka *et al*., 2015). The threat of these parasites to public health is on the increase in Nigeria, probably due to the absence of an effective food-control system, which is supposed to provide regulatory measures, monitoring systems and policies to ensure public-health protection, thus reducing the risk of food-borne illnesses and maintaining consumer confidence (Umoh & Odoba, 1999; Omemu & Aderoju, 2008). The aim of the present study, therefore, was to harness epidemiological information, including endemic zoonotic helminths, published in Nigeria between 1970 and 2016, and to determine their prevalence and distribution across Nigeria. It is envisaged that this information will help in enacting disease-control policies, encourage on-farm good agricultural

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practices, and adequate hygiene and sanitation in abattoirs and meat-processing plants, with the aim of ensuring meat safety and thus protecting public health.

Materials and methods

Study areas

Studies included in this meta-analysis were carried out in Nigeria, a country situated in Sub-Saharan Africa between latitudes 4 and 14°N and longitudes 3 and 14°E, covering a surface area of 923,768 km^2 (see supplementary fig. S1). Nigeria has two distinct seasons: the rainy and the dry seasons. While the rainy season runs from March to November in the southern region and from May to October in the northern region, the dry season runs from December to February in the south and November to April in the north (Iloeje, 2001). The major occupation of its inhabitants is agriculture, particularly crop and livestock production.

Literature search strategy and data source

The present study conducted a systematic review based on the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guideline published by Moher *et al.* (2009). Data from relevant studies were then meta-analysed to determine the prevalence and geographical distribution of zoonotic helminths in Nigeria. Inclusion of relevant information was based on the PRISMA checklist, and the infection of slaughtered food animals with zoonotic helminths was the outcome of interest.

Databases, including African Journals Online (AJOL), Google Scholar, Medline and PubMed, were systematically searched between December 2016 and May 2017 for literature on the subject of zoonotic helminths in slaughtered food animals. Several combinations, including zoonotic helminths of food animals, camels, cattle, goats, pigs and sheep, were employed during the search. Broader searches for zoonotic cestodes, nematodes and trematodes of livestock in Nigeria were also conducted. More specific searches for species of zoonotic helminths of livestock including, but not limited to, *Ascaris suum*, *Dicrocoelium* species, *Eurytrema* species, *Fasciola gigantica*, *Moniezia expansa*, *Oesophagostomum* species, *Paramphistomum* species, *Strongyloides* species and *Toxocara* species endemic in Nigeria, were also employed. Other keywords employed in the search were Nigeria, North-central, North-eastern, North-western, South-eastern, South-south, South-western regions, as well as the 36 states of the Nigerian federation. Reference lists of resultant publications were also screened to identify more studies.

Inclusion and exclusion criteria

Studies were first selected by scanning through titles and abstracts. Selected studies were further screened by detailed review of abstracts and full texts. Studies were considered for inclusion only if they fulfilled the following criteria: (1) published in English, (2) conducted between 1970 and 2016, (3) carried out within the Nigerian federation, (4) state of the Nigerian federation where the study was carried out was reported, (5) study design was cross-sectional or a prevalence study, (6) involved zoonotic helminths in slaughtered food animals as the outcome of interest, (7) number of cases and sample size were clearly provided, (8) method of diagnosis was clearly stated and (9) zoonotic helminths were identified at least to the genus level. Studies were excluded if they did not fulfil these inclusion criteria.

Extraction of data

Data extracted from the 42 eligible studies included: surname of first author for single-authored publications, surnames of both authors for studies authored by two persons and surname of first author, followed by *et al.* for studies authored by more than two people. Other data were: study design, sample size, number of cases, state and region of study, zoonotic helminths identified at least to the genus level, host, year of survey and publication, as well as method of diagnosis.

Data analysis

Data were first entered into Microsoft Excel for preliminary analysis and further transferred into Graph-Pad Prison Version 4.0 (https://www.graphpad.com/scientific-software/prism) and Comprehensive Meta-Analysis Version 3.0 (https://www.meta-analysis.com) for statistical and meta-analysis, respectively. The proportions of positive cases to sample sizes were expressed as percentages, to determine the prevalence of the individual eligible studies. The exact binomial confidence interval (http://statpages.info/confint.html) was employed to determine the 95% confidence interval (95% CI). Since the studies included in the meta-analysis were not from the same population, with varying sample sizes and diagnostic methods, it was assumed that the true-effect sizes might differ between studies and so the random-effects model was used to determine the pooled prevalence estimates of zoonotic helminths among food animals (Hedges & Vevea, 1998). The percentage of total variation across studies due to heterogeneity was quantified using the formula $I^2 = 100\% \times (Q - \mathrm{df})/Q$, where Q is Cochran's heterogeneity statistic and df the degrees of freedom, which is equal to the number of studies minus one. Negative and zero values of I^2 were all considered as zero and I^2 values of 0%, 25%, 50% and 75% were considered as having no, low, moderate and high heterogeneities, respectively (Higgins & Thompson, 2002; Higgins *et al.*, 2003).

Results

Literature search and eligible studies

The selection process of eligible studies and the list of excluded studies are presented in supplementary fig. S2 and supplementary text S1, respectively. A total of 115 studies resulted from the search of databases ($n = 86$) and lists of references of articles ($n = 29$). Forty-eight duplicate studies were removed after screening titles. Twenty-five others were excluded because: (1) they were not abattoir-based ($n = 13$), (2) they did not report any zoonotic helminth ($n = 2$), (3) helminths were not identified at least to the genus level ($n = 6$), (4) method of diagnosis (serology) was not reliable for helminths ($n = 2$) and (5) numbers of positive cases and/or sample sizes were not clearly stated ($n = 2$). Finally, 42 studies were eligible and were included in the analysis.

Characteristics of the eligible studies

The list and characteristics of the 42 eligible studies included in the meta-analysis are presented in table 1. Eligible studies were carried out between 1973 and 2015 and published between 1976 and 2016. A total of 85,466 positive cases of zoonotic

https://doi.org/10.1017/S0022149X18000196 Published online by Cambridge University Press

Table 1. List and characteristics of eligible studies included in the meta-analysis.

Study name	Year of study	Region	Host	Method of diagnosis	Sample size	Cases	Prev. (%)	95% CI
Abunza *et al*., 2008	2007	NW	CT/G/S	MI	300	100	33.33	28.02, 38.98
Adamu *et al*., 2011	2010	NE	CT/CM/G/S	MA	1,378,036	14,944	1.08	1.07, 1.10
Adedipe *et al*., 2014	2013	SW	CT	MI	397	163	41.06	36.10, 46.08
Akpabio, 2014	2012–2013	SS	CT	MI	22,259	382	1.72	1.55, 1.90
Ani & Nshiwu, 2015	2013	SE	G	MI	200	185	92.50	87.93, 95.74
Ardo *et al*., 2013	2012	NE	CT	MA	3015	657	21.79	20.33, 23.31
Babalola & Schillhorn, 1976	1973–1974	NE	CT	MA	14,270	4524	31.70	30.94, 32.47
Bamaiyi & Kalu, 2011	2010	NE	CM	MI	105	97	92.38	85.54, 96.65
Biu & Abbagana, 2007	2004	NE	CM	MA	100	29	29.00	20.36, 38.93
Biu & Ijudai, 2012	2011	NE	P	MA	247	8	3.24	1.41, 6.28
Dantanko & Idris, 2014	2012–2013	NC	CT/G/S	MI	1002	552	55.09	51.95, 58.20
Ejeh *et al*., 2015	2014	NC	CT	MA	64,978	9478	14.59	14.32, 14.86
Elele *et al*., 2013	2009–2010	SS	CT	MI	251	156	62.15	55.84, 68.18
Gana *et al*., 2015	2014	NW	G/S	MI	300	80	26.67	21.75, 32.05
Idowu *et al*., 2007	2005	SS	CT	MA	485	75	15.46	12.36, 18.99
Karshima *et al*., 2013a	2010–2012	NE	P	MA	4380	274	6.26	5.56, 7.01
Karshima *et al*., 2013b	2010–2012	NE	CT	MA	6007	288	4.79	4.27, 5.37
Karshima *et al*., 2016a	2015	NE	CT	MI	208	62	29.81	23.68, 36.52
Karshima *et al*., 2016b	2015	NE	CT	MI	208	189	90.87	86.10, 94.41
Magaji *et al*., 2011	2003–2004	NW	CM/CT/G/S	MA	80,247	379	0.47	0.43, 0.52
Magaji *et al*., 2014	2010	NW	CT	MA	224	62	27.68	21.93, 34.03
Ngele & Ibe, 2014	2011–2012	SE	CT	MI	256	93	36.33	30.43, 42.55
Nwigwe *et al*., 2013	2009	SE	CT/G	MI	939	446	47.50	44.26, 50.75
Nwoke *et al*., 2015	2013	NC	G	MI	248	183	73.79	67.85, 79.15
Odeniran *et al*., 2016	2013–2014	NC	CT/G/S	MI	2508	904	36.04	34.16, 37.96
Okolo, 1986	1985	SE	CT	MA	942	38	4.03	2.87, 5.50
Okolugbo *et al*., 2013	2010	NW	CM/CT	MA	474	89	18.78	15.36, 22.59
Okorafor *et al*., 2014	2013	SW	P	MI	101	33	32.67	23.67, 42.72
Oladele-Bukola & Odetokun, 2014	2013	SW	CT	MA	1,640,095	37,828	2.31	2.28, 2.33
Olaniyi, 2014	2013–2014	NC	P	MI	920	414	45.00	41.75, 48.28
Onah & Chiejina, 1986	1980	SE	CT	MA	374,541	1538	0.41	0.39, 0.43
Opara *et al*., 2006	2005	SE	CT	MA	25,800	6750	26.16	25.63, 26.70
Owhoeli *et al*., 2014	2010	SS	G	MI	135	106	78.52	70.63, 85.12
Oyedeji, 2016	2015	NC	CT	MI	160	55	34.38	27.06, 42.28
Qadeer, 2008	2007	NC	CT	MA	14,372	1924	13.39	12.83, 13.95
Rabiu & Jegede, 2010	2009	NW	CT	MA	11,804	315	2.67	2.39, 2.98
Schillhorn *et al*., 1980	1979	NE	CT/G/S	MI	3322	1202	36.18	34.55, 37.84
Shitta & James-Rugu, 2013	2012	NE	CT	MI	350	122	34.86	29.87, 40.10
Sowemimo *et al*., 2012	2010	SW	P	MI	271	97	35.79	30.08, 41.82
Tidi *et al*., 2011	2010	NC	P	MI	502	333	66.33	62.01, 70.46
Tijani *et al*., 2010	2006	NE	G/S	MA	116,373	31	0.03	0.02, 0.04
Yohanna *et al*., 2012	2011	NC	CT/G/S	MI	500	281	56.20	51.73, 60.60

CI, confidence interval; CM, camel; CT, cattle; G, goat; MA, macroscopy; MI, microscopy; NC, north-central; NE, north-east; NW, north-west; P, pig; Prev., prevalence; S, sheep; SE, south-east; SS, south-south; SW, south-west.

https://doi.org/10.1017/S0022149X18000196 Published online by Cambridge University Press

helminths were reported from 3,771,832 food animals slaughtered during the period under review. Nine and 13 studies were reported from north-central and north-east regions, respectively, six each from north-west and south-east regions, and four studies each from south-south and south-west regions. Six studies each reported zoonotic helminths in camels and pigs, while 8, 13 and 29 of the studies reported zoonotic helminths in sheep, goats and cattle, respectively. Four of the studies were carried out between 1973 and 1986, 2 between 1987 and 2004 and 36 between 2005 and 2015. Nineteen and 23 of the studies were diagnosed using macroscopy and microscopy, respectively (table 2).

Pooled prevalence estimates and heterogeneity analyses

Pooled prevalence estimates and heterogeneities are presented in table 2, figs 1–3 and supplementary figs S3 and S4. An overall pooled prevalence estimate (PPE) of 2.27% (95% CI: 2.25, 2.28%) was observed from 42 eligible studies that reported 85,466 cases from 3,771,832 food animals slaughtered in Nigeria during the period under review. PPEs across the six geographical regions ranged between 1.10% (95% CI: 1.03, 1.17%) and 16.58% (95% CI: 16.33, 16.83%). PPEs for hosts ranged between 1.00% (95% CI: 0.97, 1.03%) and 18.05% (95% CI: 17.12, 19.01%). The PPEs ranges for survey dates and diagnostic methods were 0.51% (95% CI: 0.46, 0.56%) to 2.36% (95% CI: 2.34, 2.37%) and 2.12% (95% CI: 2.11, 2.14%) to 17.59% (95% CI: 17.20, 17.99%). Substantive heterogeneities ranging between 97.10% (95% CI: 2.64, 2.68%, *P*: 0.000) and 99.99% (95% CI: 1.82, 1.90%, *P*: 0.000) were observed within studies and sub-groups. *Ascaris suum* was the most prevalent helminth, with a prevalence of 25.46% (95% CI: 24.04, 26.92%), followed by *Strongyloides* species 23.77% (95% CI: 22.59, 24.97%), while *Echinococcus* species recorded the lowest prevalence of 0.08% (95% CI: 0.07, 0.08%) (table 3).

Regional distribution of eligible studies and helminth species

A total of 42 studies reported zoonotic helminths in food animals slaughtered across Nigeria between 1970 and 2016. Nine (21.43%) of the studies were reported from the north-central region and were distributed as follows: Benue and Kogi, 1 study (2.38%) each; Abuja and Kwara, 2 studies (4.76%) each; and Plateau, 3 studies (7.14%). The distributions of the 13 (30.95%) studies reported from the north-east were as follows: Yobe, 1 (2.38%); Adamawa, 2 (4.76%); Borno and Taraba, 3 studies (7.14%) each; and Bauchi, 4 (9.52%). Of the 6 studies (14.29%) reported from the north-west region, 1 (2.38%) each was from Kaduna and Kano states and 4 (9.52%) were from Sokoto state. Another set of 6 studies (14.29%) reported across the south-east region were distributed as follows: Anambra, 1 (2.38%); Enugu, 2 (4.76%); and Ebonyi, 3 (7.14%). Four studies (9.52%) were reported in Rivers, south-south region, while 1 (2.38%) and 3

Table 2. Pooled prevalence of zoonotic helminths in food animals stratified according to sub-groups.

		Pooled prevalence estimates				Heterogeneity	
Variable	Number of studies	Sample size	Cases	Prev. (%)	95% CI	I^2	*Q-P*
Region							
North-central	9	85,190	14,124	16.58	16.33, 16.83	99.78	0.000
North-east	13	1,526,621	22,427	1.47	1.45, 1.49	99.98	0.000
North-west	6	93,349	1025	1.10	1.03, 1.17	99.82	0.000
South-east	6	402,678	9050	2.25	2.20, 2.29	99.98	0.000
South-south	4	23,130	719	3.11	2.89, 3.34	99.82	0.000
South-west	4	1,640,864	38,121	2.32	2.30, 2.35	99.84	0.000
Host							
Camel	6	223,336	3376	1.51	1.46, 1.56	99.85	0.000
Cattle	29	2,614,364	70,752	2.66	2.64, 2.68	97.10	0.000
Goat	13	495,802	7050	1.42	1.39, 1.46	99.94	0.000
Pig	6	6421	1159	18.05	17.12, 19.01	99.60	0.000
Sheep	8	431,909	4331	1.00	0.97, 1.03	99.51	0.000
Year of study							
1970–1986	4	393,075	7302	1.86	1.82, 1.90	99.99	0.000
1987–2004	2	80,347	408	0.51	0.46, 0.56	99.74	0.000
2005–2016	36	3,298,410	77,756	2.36	2.34, 2.37	99.97	0.000
Method of diagnosis							
Macroscopy	19	3,736,390	79,231	2.12	2.11, 2.14	99.98	0.000
Microscopy	23	35,442	6235	17.59	17.20, 17.99	99.61	0.000
Overall	42	3,771,832	85,466	2.27	2.25, 2.28	99.97	0.000

CI, confidence interval; I^2, inverse variance index; Prev., prevalence; *Q-P*, Cochran's *P* value.

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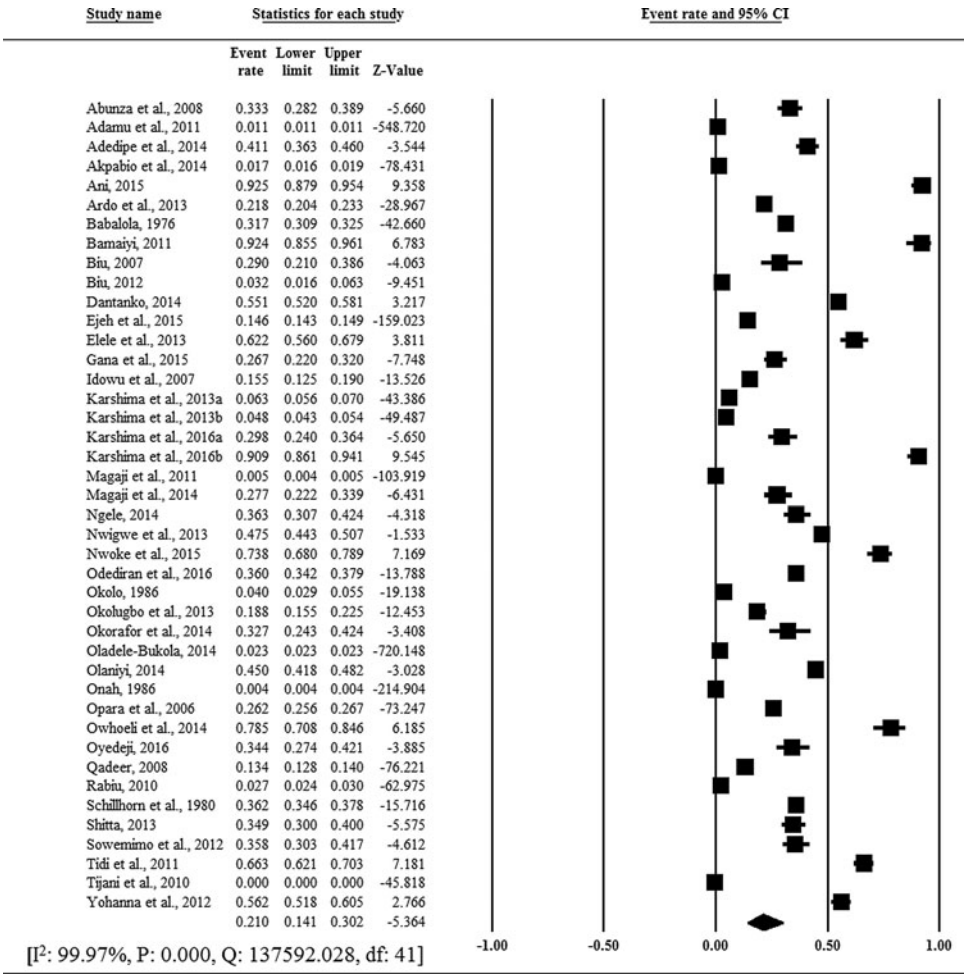

Fig. 1. Forest plot for the prevalence of zoonotic helminths in slaughtered food animals in Nigeria. Only the first names of authors are given.

studies (7.14%), respectively, were reported from Ogun and Oyo states, south-west region, as presented in supplementary fig. S1.

Fasciola gigantica, which was reported in 19 (45.24%) of the 42 eligible studies, had the widest geographical distribution. This was followed by *A. suum*, which occurred in 9 (21.43%) of the studies (table 3). *Fasciola gigantica* was the only species reported across the six geographical regions of Nigeria. This was followed by *M. expansa*, *Paramphistomum*, *Strongyloides* and *Taenia saginata/Cysticercus bovis*, which occurred in at least five of the regions. *Echinococcus*/hydatid cysts, which occurred in only one region, had the lowest regional distribution (figs 4–6).

Discussion

Knowledge of endemic helminths in a resource-limited country such as Nigeria is essential for their diagnosis, treatment and cost-effective control. In view of this, the present study, which provides epidemiological information on endemic zoonotic helminths in slaughtered food animals, their prevalence and distribution across Nigeria, was necessary to provide national data on these parasites, which were presently lacking. For this purpose, the study meta-analysed 42 published studies with 85,466 positive cases from 3,771,832 food animals, including camels, cattle, goats, pigs and sheep. To the author's knowledge, this meta-analysis is the first to report the prevalence and distribution of zoonotic helminths in slaughtered food animals in the entire Nigerian federation.

Results revealed an increase in the pooled prevalence of zoonotic helminths in food animals slaughtered for human consumption in Nigeria in recent times. This may be due to poor hygiene and sanitation, inadequacy of veterinary services, indiscriminate and open defecation by animals and humans, lack of effective policies on disease control, as well as uncontrolled importation of food animals from neighbouring countries, including Niger, Chad and the Republic of Cameroon, for slaughter in Nigerian abattoirs. This suggests the need to improve the existing control programmes for zoonotic helminths and to prevent uncontrolled importation of food animals.

The high prevalence among pigs may be explained by the omnivorous nature of this animal species, which might have resulted in the consumption of pasture contaminated with eggs or larvae of these parasites, tissues of infected animals or even human stools infected with these zoonotic helminths. The majority of Nigerian pigs are usually raised under extensive management systems, especially during the dry season when farm crops have already been harvested, and this may be an influencing factor for contact with these infections.

The north-central region recorded the highest prevalence estimate, which might be due to variations in environmental factors, including temperature, humidity, altitude and rainfall. Other human-related factors that might have contributed to this

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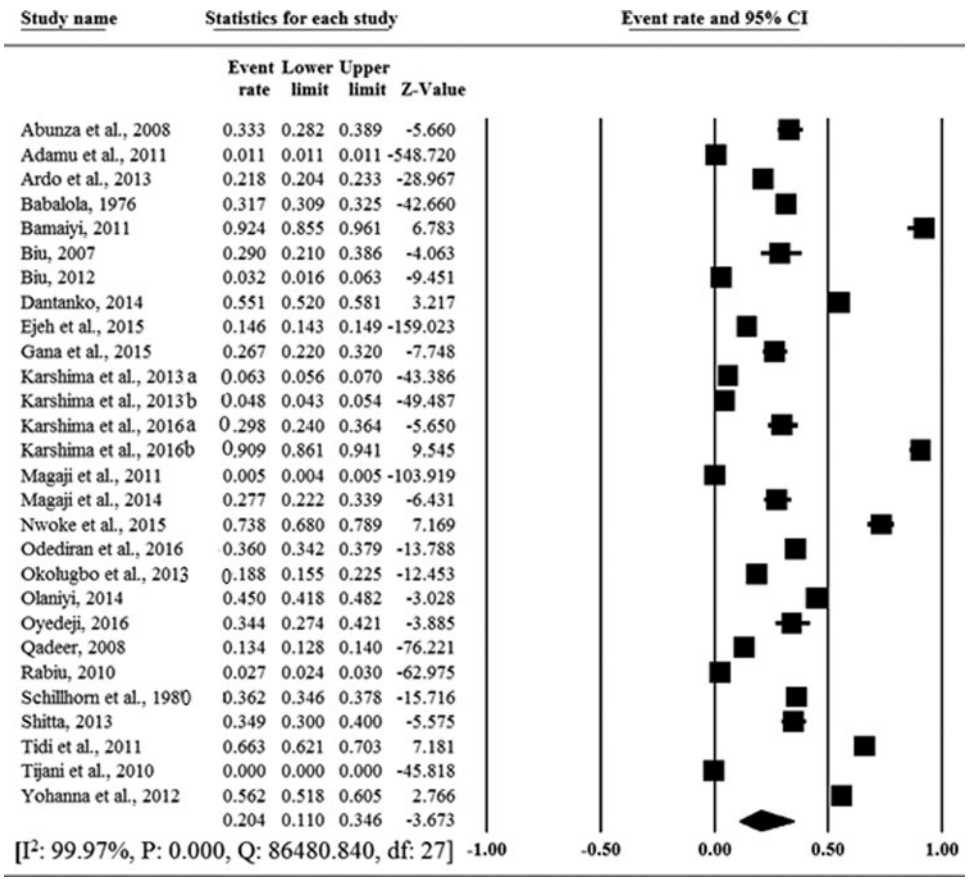

Fig. 2. Forest plot for the prevalence of zoonotic helminths in food animals slaughtered in northern Nigeria. Only the first names of authors are given.

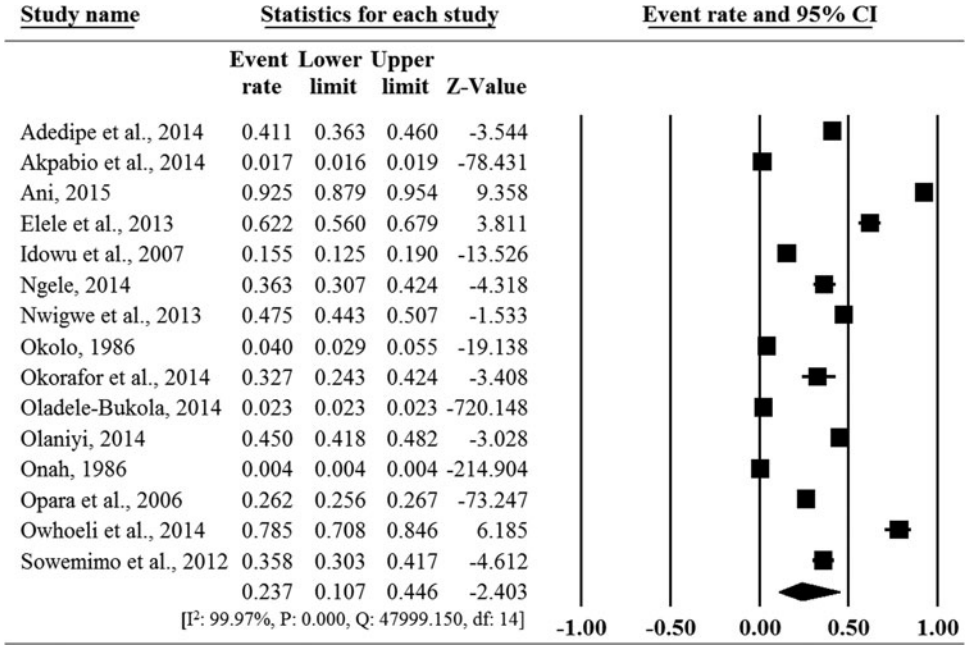

Fig. 3. Forest plot for the prevalence of zoonotic helminths in food animals slaughtered in southern Nigeria. Only the first names of authors are given.

prevalence are inadequate knowledge of the risk of acquiring zoonotic helminths from food animals, poor agricultural practices on farms, lack of strategic de-worming of food animals (World Health Organization, 2002) and season of study (Brooker & Michael, 2007). Most of the studies (30.95%) documented in Nigeria during the period under review were in the north-eastern region, probably due to collapse of disease control programmes in the region as a result of political insecurity.

https://doi.org/10.1017/S0022149X18000196 Published online by Cambridge University Press

Table 3. Pooled prevalence of zoonotic helminths in food animals stratified according to phylogenetic groups.

		Pooled prevalence estimates				Heterogeneity	
Parasite	Number of studies	Sample size	Cases	Prev. (%)	95% CI	I^2	*Q-P*
Cestoda							
Echinococcus/hydatid cyst	3	1,458,757	1112	0.08	0.07, 0.08	99.96	0.000
Moniezia expansa	8	3018	518	17.16	15.83, 18.56	98.10	0.000
Taenia saginata/C. bovis	10	421,176	9221	2.19	2.15, 2.23	99.98	0.000
Taenia solium/C. cellulosae	2	4875	465	9.54	8.73, 10.40	72.04	0.059
Total	24	1,888,212	11,328	0.60	0.59, 0.61	99.98	0.000
Nematoda							
Ascaris suum	9	3594	915	25.46	24.04, 26.92	98.93	0.000
Oesophagostomum species	5	1399	154	11.01	9.42, 12.77	72.21	0.006
Strongyloides species	8	5024	1194	23.77	22.59, 24.97	99.42	0.000
Toxocara vitulorum	2	557	11	1.97	0.99, 3.51	82.21	0.018
Total	24	10,574	2,274	21.51	20.73, 22.30	98.49	0.000
Trematoda							
Dicrocoelium dendriticum	7	7901	752	9.52	8.88, 10.19	98.92	0.000
Eurytrema pancreaticum	3	594	71	11.95	9.45, 14.84	96.64	0.000
Fasciola gigantica	19	3,146,600	57,054	1.81	1.80, 1.83	99.97	0.000
Paramphistomum species	8	6029	772	12.80	11.97, 13.67	96.94	0.000
Total	37	3,161,124	58,649	1.86	1.84, 1.87	99.94	0.000

CI, confidence interval; I^2, inverse variance index; Prev., prevalence; *Q-P,* Cochran's *P* value.

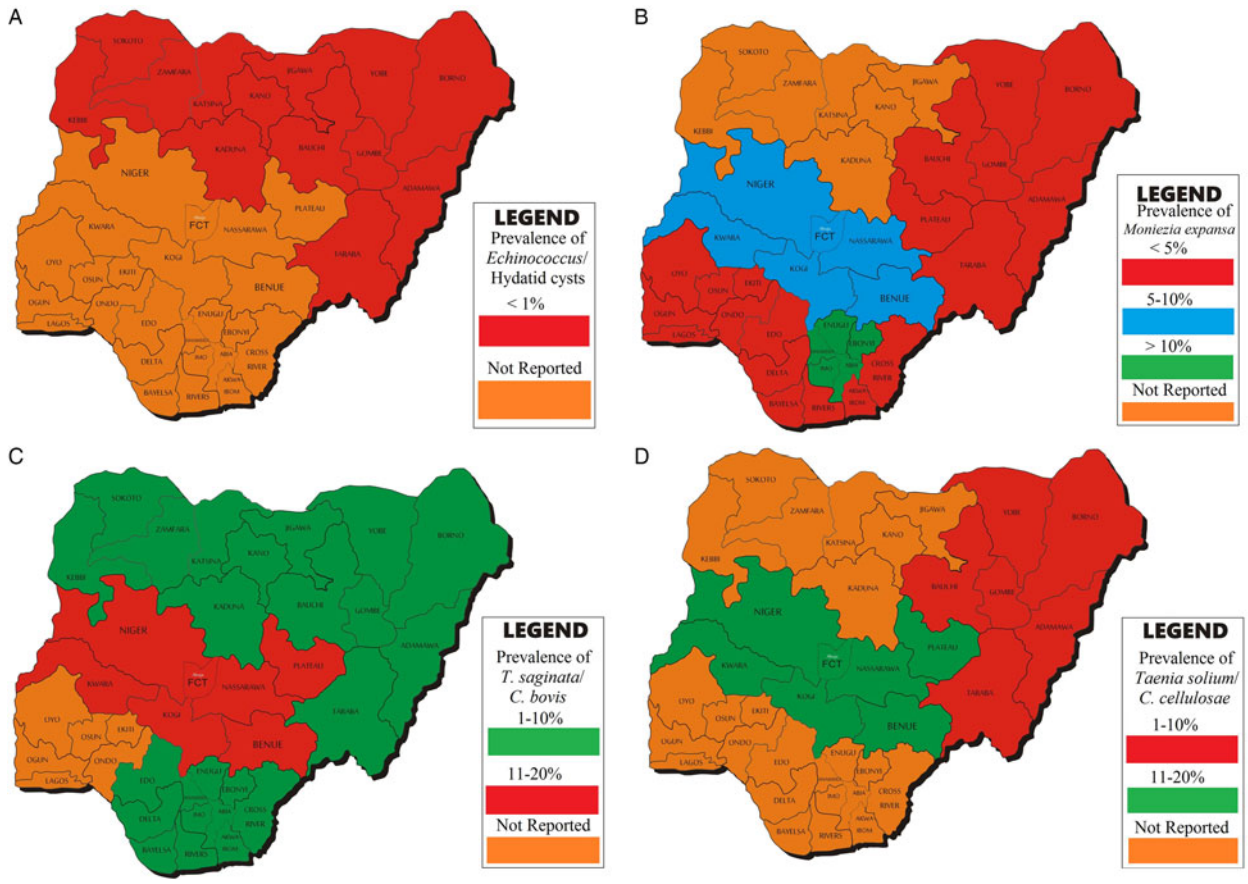

Fig. 4. Regional prevalence of zoonotic species of cestodes in slaughtered food animals in Nigeria.

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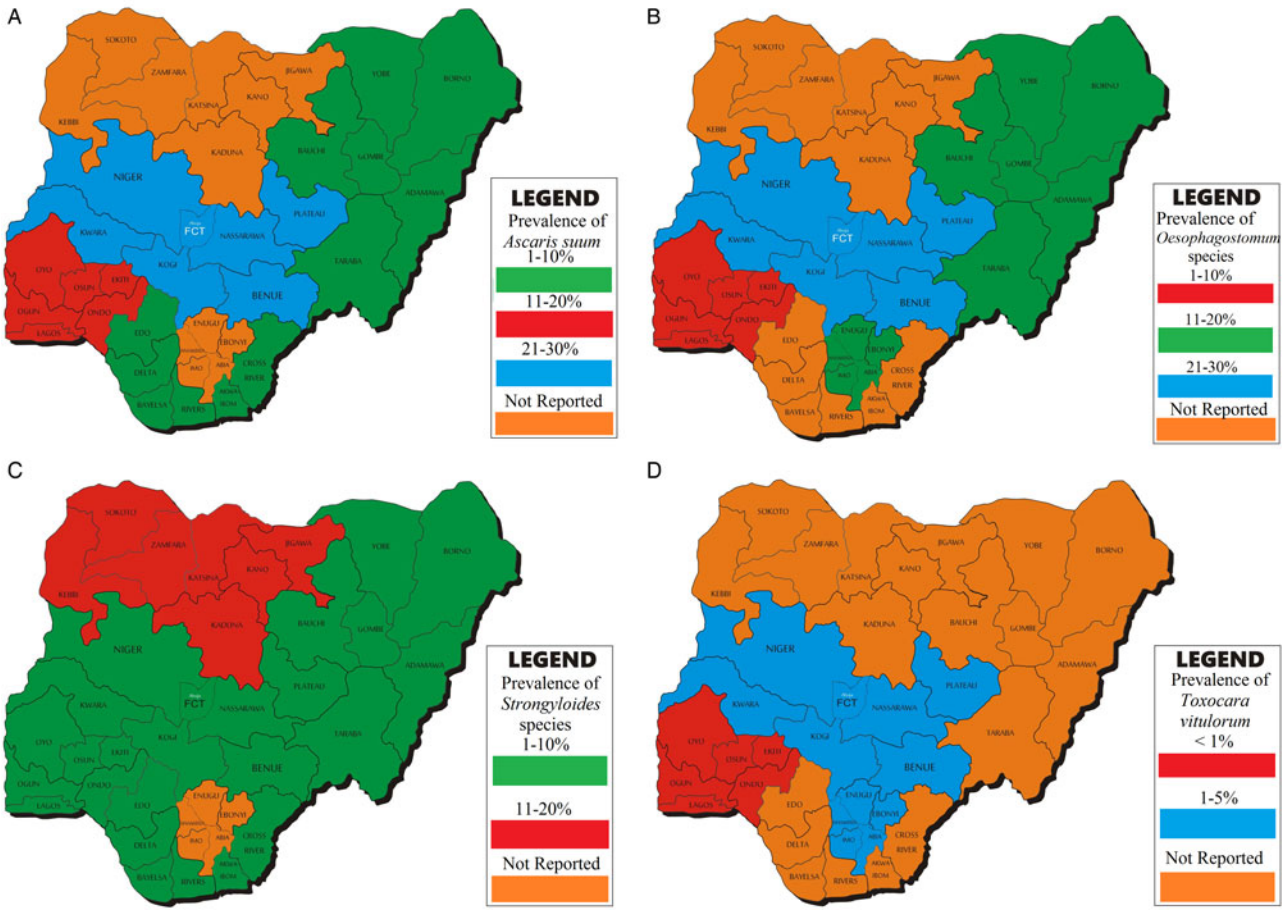

Fig. 5. Regional prevalence of zoonotic species of nematodes in slaughtered food animals in Nigeria.

The literature showed that the zoonotic helminths reported in this study were also reported in slaughtered animals elsewhere (Theodoropoulos *et al.*, 2002; Kabir *et al.*, 2010; Khanjari *et al.*, 2014; Mhoma *et al.*, 2014). The overall prevalence estimate observed in this study is higher than the 0.26% reported in Greece (Theodoropoulos *et al.*, 2002). This prevalence is, however, much lower than the range of 23.3–81.3% reported in other resource-limited countries (Ntonifor & Ndaleh, 2012; Ezatpour *et al.*, 2014). These variations may be attributable to differences in levels of hygiene and sanitation, as well as factors including temperature, humidity and soil moisture, which influence the survival of helminth eggs and larvae in the environment.

The high fecundity of helminths of the genus *Ascaris* and the sticky nature of the shell of their eggs, which increases their chances of attachment on pasture in grazing areas, may explain the higher prevalence of *A. suum* observed in the present study. Reports of *Fasciola*, *Eurytrema* and *Dicrocoelium* species in humans in other countries (Ishii *et al.*, 1983; Jack *et al.*, 2004; Le *et al.*, 2008; González *et al.*, 2011) suggest that the presence of these parasites in food animals in Nigeria is a potential public-health threat.

Individual prevalence estimates for helminths of public-health importance, such as *Cysticercus cellulosae* (9.54%), *C. bovis* (2.19%), hydatid cyst (0.08%) and *F. gigantica* (1.81%) were all on the lower limits of the ranges of 0.7–34.4% (Porphyre *et al.*, 2015; Qekwana *et al.*, 2016; Thomas *et al.*, 2016), 0.16–77.3% (Otupiri *et al.*, 2000; Garedaghi *et al.*, 2011; Fonteh *et al.*, 2016), 3.4–90.65% (Kabir *et al.*, 2010; Taghavi *et al.*, 2013; Mhoma *et al.*, 2014) and 2.15–26.51% (Otupiri *et al.*, 2000; Yilma & Mesfin, 2000; Jean-Richard *et al.*, 2014), respectively, documented in other resource-limited countries. The fact that the prevalence rates reported in this study are pooled estimates of several studies may explain why they were at the lower limits of these documented ranges.

Mapping of individual helminth species shows that *F. gigantica* was the only species distributed across all the six geographical regions of the country. This may be attributed to the abundance of freshwater snail intermediate hosts, as is shown by published literature in Nigeria (Prasertphon, 1990; Okpala *et al.*, 2010; Kalu *et al.*, 2012; Luka & Mbaya, 2015), and the ability of one miracidum from a single *Fasciola* egg to produce 4000 infective metacercariae through vegetative multiplication (Uhuo *et al.*, 2013). Mapping also revealed a wide distribution of helminth species transmitted by arthropods (*Moniezia, Paramphistomum*), gastropods (*Fasciola, Eurytrema*), soil and pasture (*Oesophagostomum, Strongyloides*) and meat (*C. cellulosae,* cystic echinococcosis) across different regions of Nigeria. This finding is a clue that helminth control in Nigeria must adopt a more inclusive strategy, involving public education, hygiene and sanitation, strategic use of anthelmintics, rotational grazing and the control of arthropod and gastropod intermediate hosts.

Macroscopy (gross identification of parasites) and microscopy (the use of light microscopy) were the two methods employed by the individual studies analysed. While macroscopy was used for

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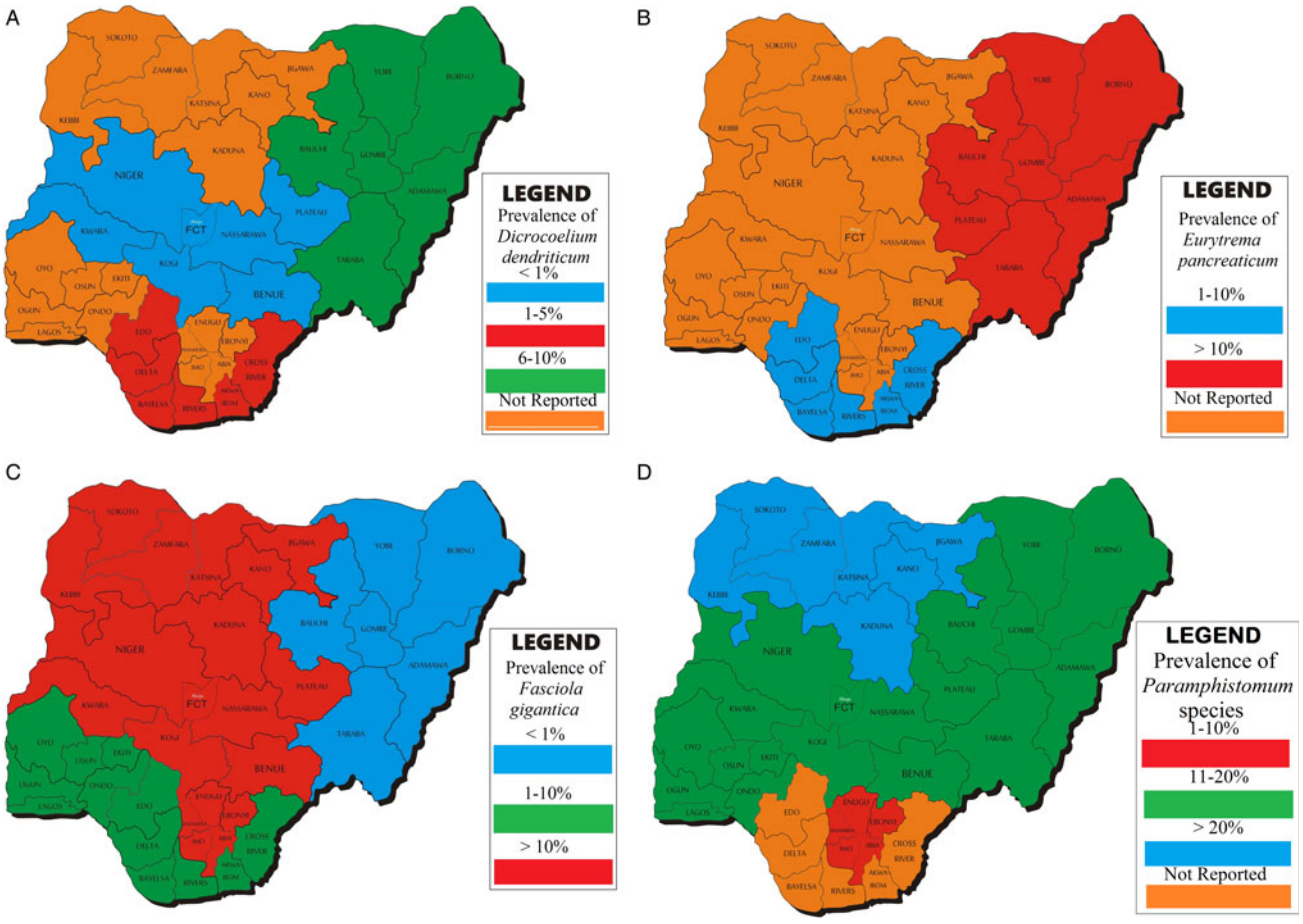

Fig. 6. Regional prevalence of zoonotic species of trematodes in slaughtered food animals in Nigeria.

the identification of *F. gigantica* and cystic conditions caused by metacestodes during veterinary meat inspection in abattoirs, microscopy was used for the detection of eggs and larval stages of helminths. Current molecular techniques, which are highly sensitive and specific, are recommended for use in present research on helminths, for a better understanding of the epidemiology of zoonotic species of helminths in Nigeria.

The implications of this finding on public health are that some of the reported cases of human zoonotic helminth infections in Nigeria would have resulted from the consumption of these food animals. The association of *C. cellulosae* in ocular cysticercosis, neuro-cysticercosis and epilepsy, as well as hydatid cysts, and *F. gigantica* in liver injuries are particularly of great concern. The poor attitude of veterinarians towards veterinary meat inspection, the dilapidated state of Nigerian abattoirs, lack of standardized equipment for meat inspection and inadequate policies on disease control are possible factors that may influence transmission to humans in Nigeria.

This analysis revealed a high degree of heterogeneity between studies and even sub-groups, which may be due to variations in study designs, sample sizes, diagnostic methods and study populations of the eligible studies, among others. This implies that, despite the valuable epidemiological information provided by this analysis, it might not give a completely true picture of the prevalence of zoonotic helminths in the whole of Nigeria. The fact that other states of the Nigerian federation were not included in the meta-analysis, due to lack of literature on this subject or absence of inclusion criteria in published studies, also suggests that this may not be absolutely the true situation for Nigeria. Another limitation is that studies were unevenly distributed across the six regions of Nigeria and over time.

The present study revealed a low prevalence of zoonotic helminths in food animals slaughtered for human consumption in Nigeria. *Fasciola gigantica* had the widest geographical distribution, while *A. suum* was the most prevalent of all the zoonotic helminths. Although the highest numbers of cases were reported in the north-east, the north-central region recorded the highest prevalence of zoonotic helminths. The study also revealed: (1) that cattle may be the most important source of human zoonotic helminth infections; (2) an increase in the prevalence of zoonotic helminths in recent times; and (3) a high degree of heterogeneity between studies. Adequate zoonotic disease control policies, which ensure monitoring systems across the food chain, good agricultural practices, proper cooking of meat from food animals, adequate hygiene and sanitation, and attitudinal changes are recommended to ensure the wholesomeness of meat and to curtail the transmission of zoonotic helminths from food animals to humans.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S0022149X18000196.

Financial support. This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of interest. None.

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