

Systematic Review

Where literature is scarce: observations and lessons learnt from four systematic reviews of zoonoses in African countries

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Abstract

The success of a systematic review depends on the availability, accessibility and quality of literature related to the review question. This paper presents the literature found in four systematic reviews conducted for a selection of zoonotic hazards in four livestock value chains in Africa, as well as setting out the challenges in conducting the reviews. The protocol was designed following international standards, and addressed four questions around prevalence, risk factors, control options and impact of various hazards and populations. Searches were conducted in four online databases. Articles were screened for relevance, and quality was assessed before data extraction. Literature on zoonotic hazards was in general scarce and access to full articles was limited. Overall, 25–40% of papers were considered poor quality. The diversity of approaches and designs in the studies compromised the ability to generate summarized estimates. We found that the emphasis of veterinary research has been on livestock problems rather than public health issues, although this seems to be shifting in the last decade; we also found there are limited studies on impact and control. While increasing literature is being published around zoonoses in Africa, this is still inadequate to appropriately inform policy and guide research efforts.

Keywords: zoonotic hazards, systematic literature review, Africa, livestock.

Introduction

Increasing amounts of research are generated and published every year. The speed at which new results are released makes it challenging for users to keep up with new findings.

Literature reviews can have an important role in synthesizing evidence. Systematic reviews (SRs) use explicit and reproducible methods to systematically search, critically appraise, and synthesize a specific issue, enabling increased and more efficient access to evidence (Petticrew, 2001; Gopalakrishnan and Ganeshkumar, 2013; Sargeant and O'Connor, 2014b). However, a review is only as good as the papers it draws on. Research efforts are not everywhere equal, and the target topics of research do not always reflect the

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priorities of countries. While SRs are increasingly common in developed countries, less is known about their applicability to questions where most of the data is drawn from research conducted and published in developing countries and where the focus is a relatively neglected topic, such as zoonoses of livestock (Schelling *et al.*, 2007).

In developing countries, entire societies rely on the income and products that derive from livestock production, and livestock farmers often live in close contact with their animals. Outbreaks of emerging infectious diseases, such as Ebola, Rift Valley fever, and avian influenza demonstrate the social, economic, and health impacts of zoonotic pathogens (Meslin *et al.*, 2000; Cutler *et al.*, 2010). While these emerging threats generate much media and international attention, endemic zoonotic infections (including those caused by foodborne pathogens) receive less attention; many of these are underreported and their real burden on people's health and wellbeing is unknown (ILRI, 2012). However, the greatest burden of neglected zoonoses is borne by developing countries (Grace *et al.*, 2012b). Work by the World Health Organization (WHO) Foodborne Disease Burden Epidemiology Reference Group (FERG) has found that foodborne disease (with zoonotic bacteria as leading causes) has a health burden similar to malaria, HIV, and AIDs, or tuberculosis worldwide, and that 98% of this was borne by developing countries (WHO, 2015). The greater health burden in developing countries is attributable partly to a larger population, but also greater interaction with, and dependence on, animals; insufficient infrastructure to contain and manage disease in animals; and, high levels of poverty and inadequate human health provision (Thornton, 2010; Herrero and Thornton, 2013; FAO, 2014; Halliday *et al.*, 2015). Low-income countries often lack an evidence base for planning and targeting control efforts (Schelling *et al.*, 2007); this has been attributed to limited knowledge of zoonotic causes of human disease by health professionals and policy makers; fragmentary data collection and reporting systems; lack of diagnostic capacities; lack of reference laboratories; and, lack of reliable qualitative and quantitative data on zoonotic diseases burden. Moreover, decision making on veterinary public health management is still hazard-based rather than risk-based; that is, it is based more on the presence of pathogens than their impact on human health. These facts undermine all efforts to successfully develop and implement evidence-based policies to manage public health threats.

Evidence-based policy making requires enough sound scientific work around a specific topic, but also the unbiased interpretation and meaningful synthesis of findings from various researches. Systematic review and meta-analysis are considered the gold standard approaches to obtaining the most compelling and strong evidence base. SRs can also be used to identify lack of evidence, and direct future research efforts (Sargeant and O'Connor, 2014b). Their traditional use has been in the clinical field and, although their ability to answer broader public health questions has been questioned (Petticrew, 2001), the recently-formed Cochrane public health group (<http://ph.cochrane.org/>) aims to promote the production and publication of population-level interventions. Despite the different nature of interventions in livestock and agri-food systems, the use of SRs in veterinary medicine and agriculture is increasing (Sargeant *et al.*, 2006). The success and ultimate

usefulness of a SR depend on the amount and soundness of the available scientific work, and its ease of access.

As part of a multi-country research project to develop standardized tools to carry out Rapid Integrative Assessments (RIA) of Food Safety and Nutrition (<http://livestockfish.cgiar.org/2013/03/22/assessing-food-safety-and-food-nutrition/>) a protocol and research tools were developed to carry out systematic literature reviews of foodborne and zoonotic hazards in selected livestock value chains (LVC) in developing countries. The SRs were intended to provide baseline information/data on the prevalence of zoonotic and foodborne hazards, risk factors, impacts, and control. Ultimately, the outcomes from the SRs were expected to help prioritize pathogens at the LVC-country level and inform the subsequent research and development activities. This paper offers a retrospective reflection on the SR process, presenting the findings from four different SRs, carried out on different value chains and regions, in terms of the literature availability and quality, highlighting challenges associated with conducting SRs to answer public health questions of relevance to developing countries. We further discuss the limitations of the SR approach where literature is scarce and access is limited, as well as the implications for evidence-based decision making in low-income countries. This paper does not present findings of the SRs, which will be the focus of subsequent publications (e.g., Alonso *et al.*, 2016).

Materials and methods

The overall aim of the SRs was to summarize the available literature on a selection of human health hazards associated with specific animal value chains in given low-income countries. The SR was used in the following LVC-country combinations:

- Bovine value chain in Tanzania
- Pig value chain in Uganda
- Small ruminant (sheep and goat) meat value chain in West Africa (Senegal, Mali, Mauritania, Côte d'Ivoire and Burkina Faso)
- Fish (tilapia) value chain in Egypt.

The protocol for systematic search of scientific literature was developed based on best practices outlined in relevant literature (O'Connor *et al.*, 2014; Sargeant and O'Connor, 2014a) and included the following steps:

- Identifying the research gap and framing the research question(s)
- Selecting the literature databases to search
- Developing search criteria (constraints) and search syntax for each database
- Developing inclusion/exclusion and quality criteria
- Screening of titles and abstracts according to inclusion/exclusion criteria
- Reviewing selected full papers on the basis of inclusion and quality criteria
- Developing a data extraction file
- Extracting data from selected papers

The protocol included a detailed step-by-step guide on the SR process that was to be adapted to the specifics of each LVC in

each country (see supplementary material S1). It also included a standardized template for data extraction, also intended for adaptation to the specific LVC-country requirements. The reviews were broad, as targeting many hazards and various hosts and to account for the expected limited literature on the topic, but the research questions were focused. For each review, the SR aimed to address the following research questions (an example of an adapted PICOS question is also provided):

- What is the prevalence of the selected hazards in the target animal species and food products in the target country? (e.g. what is the prevalence of *Brucella* spp. infection in cattle in Tanzania)
- What are the risk factors for each of the selected hazards in each of the selected populations in the target area? (e.g. What are the risk factors for *Brucella* spp. infection in cattle in Tanzania)
- What impacts does each of the selected hazards in the target population have in the target area (including (i) overall disease burden (DALYs: Disability-adjusted life year¹), (ii) economic burden (at individual or population levels), (iii) health, (iv) social, (v) environment)? (e.g. What type of impacts does *Brucella* spp. in cattle has in Tanzania?)
- What are the available control strategies for each of the selected hazards and what is their effectiveness in the selected populations in the target areas? (e.g. what are the available control strategies for *Brucella* spp. in cattle in Tanzania and their effectiveness)

Public health hazards of interest were identified for each country-LVC. This was done primarily based on the hazard prioritization presented in Grace *et al.* (2012a) followed by consultation of international and local public health experts to adjust to the local context, aiming at being inclusive and comprehensive. These included foodborne hazards (biological and chemical) and zoonoses (direct and vector-borne) (Table 1).

Online searches

Searches were conducted in the following online databases: PubMed, CabDirect, Web of Science (WoS) and African Journals Online (AJOL). The databases were selected so as to ensure the broadest possible coverage of scientific literature, including African journals. In West Africa, in order to reach the French scientific literature, searches were conducted in Google Scholar using French syntax. Search syntax was developed for each database using the following generic format: (list of hazards) AND (animal source food OR animal) AND (country). The syntax was left generic so as to reach all literature covering the various aspects of interest (e.g. prevalence, impact, risk factors, control). A detailed description of the syntax is given in the supplementary material (S1). The searches were limited to literature published on or before December 2012 (June 2013

in the case of the Egypt SR) and, in the case of the review in West Africa and Uganda, not older than 1988 and 1990, respectively. Only publications written in English were included in the review, except for the West Africa review, which explicitly targeted French literature in addition to English. Searches outside of electronic databases were not conducted. The PRISMA 2009 (Moher *et al.*, 2009) flow diagram was used to document the systematic review process.

Screening of titles and abstracts

Upon searching the online databases, full lists of titles and abstracts were downloaded, and duplicates identified and removed manually, except in the case of the Tanzania SR in which duplicates were removed using Mendeley Reference Manager (<http://www.mendeley.com>). Titles and abstracts were then blind screened (all features apart from titles and abstract were removed) by at least two independent reviewers and assessed against relevance (inclusion and exclusion) criteria (see Table 2); articles scored as 'relevant' by at least one reviewer were retained for further review.

Bibliographic databases were created in Mendeley Reference Manager. Full papers from 'selected' titles were downloaded online or through institutional libraries, when available. If not available, corresponding authors were contacted to request a copy of the article (except for the West Africa and Egypt reviews).

Review of papers and data extraction

The reviewing and data extraction team consisted of 2–4 reviewers. All reviewers had research experience, and were conversant with basic concepts of epidemiology, as well as public health. Quality criteria were developed and agreed prior to starting review of full papers. These covered two main aspects: evidence of robust epidemiological approaches (e.g. unbiased methods, appropriate data analysis, comprehensive data collection) and rigorous reporting of methods, approaches and results (i.e. paper contains all the required information to judge quality and scientific soundness, and to extract required data). Table 3 provides more specifics of quality criteria applied to reviewed literature. According to these criteria, papers were categorized as poor, medium or high quality. Quality criteria were only applied to full papers, and not to abstracts, given the limited information available in the latter.

A data extraction template was prepared as an Excel file to facilitate standardized extraction of detailed data on prevalence and risk factors for each hazard (supplementary material S2). The data on control and impact was expected to be less structured and more of qualitative nature in the literature, and therefore the data extraction template was not restrictive (i.e. did not require extraction of information on specific variables but rather allowed extraction of messages and relevant pieces of information), allowing more flexibility for the extraction of information (Popay *et al.*, 1998). Data was extracted from both full papers and, to the extent possible, from abstracts (when the full

¹Number of years lost due to ill-health, disability or early death (WHO, http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/)

Table 1. List of hazards targeted in each SR

Country – value chain	Foodborne non-zoonotic	Foodborne zoonotic	Not exclusively foodborne
Tanzania – bovine	Salmonella typhi Mycotoxins Antibiotic residues	Campylobacter spp. (Toxigenic) E. coli Salmonella spp. Staphylococcus spp. Clostridium perfringens Bacillus cereus Cryptosporidium spp.	Leptospira spp. Mycobacterium spp. Brucella spp. Rabies virus Bacillus anthracis Rift Valley fever virus Q fever (Coxiella burnetii) Trypanosoma spp. Leptospirosis Bacillus anthracis Brucella suis
Uganda – pigs	Antibiotic residues Heavy metals Mycotoxins Pesticides Blue pork	Toxoplasma spp. Alaria alata Ascaris suum Cryptosporidium spp. Echinococcus spp. (Toxigenic) E. coli Giardia duodenalis Hepatitis E Salmonella spp. Sarcocystis suihominis Taenia solium, larval Toxoplasma gondii Trichinella spp. Trichuris suis Campylobacter spp. Yersinia enterocolitica Toxoplasma gondii	Q-fever (Coxiella burnetii) Erysipelothrix rhusiopathiae Influenza Mycobacterium spp. Rabies Mange (Sarcoptes scabiei var. suis) Streptococcus suis Trypanosoma spp. Jiggers (Tunga penetrans) Ebola Globocephalus spp. Relapsing fever (Borrelia duttonii) Trypanosoma spp.
West Africa – meat small ruminants	Antibiotic residues Heavy metals	Cryptosporidium spp. Echinococcus spp. (Toxigenic) E. coli Giardia duodenalis Salmonella spp. Bacillus cereus Coccidia spp. Mycoplasma agalactiae Salmonella spp.	Bacillus anthracis Q-fever (Coxiella burnetii) Rift Valley fever virus Influenza virus Brucella spp. Chlamydia spp. Helminths
Egypt – Tilapia	Total PCB residues Pentachlorophenol (PCPs) Heavy metals: mercury, cadmium, lead, arsenic Pesticides	Vibrio spp. V. parahaemolyticus Listeria monocytogenes Staphylococcus aureus	

paper was not available). The data extraction files consisted of the following spreadsheets:

- Selection process – full list of titles and documented decisions regarding (i) inclusion/exclusion based on agreed criteria, (ii) exclusion due to other reasons (i.e. books), (iii) exclusion based on quality criteria.
- Prevalence – Titles and data extracted on prevalence
- Risk factors – Titles and data extracted on risk factors
- Control – Titles and data extracted on control
- Impact – Titles and data extracted on impact

Reviewers read the full paper and abstracts (when full paper was not available), and (i) excluded irrelevant articles (according to inclusion/exclusion criteria), (ii) judge the quality of the selected article (only for full papers) and (iii) extracted the data.

Ten per cent of the full papers and abstracts (when the full paper was unavailable) were reviewed in parallel by all reviewers in two separate rounds. A meeting was held after each round to compare reviewers' decisions on inclusion/exclusion, quality and data to be extracted; discussions were held and consensus reached. The data extraction template was reviewed according to the reviewers' feedback, to address the limitations encountered and help make the data extraction process standard. The remaining papers (90%) were each reviewed by just one reviewer.

Data analysis

We summarized descriptively the size and the quality of the body of literature for each of the SRs. In addition, we explored

Table 2. Inclusion/exclusion criteria

Inclusion criteria	Exclusion criteria
Reporting the presence of relevant hazard in the target hosts (animal, animal source foods, people and wildlife) OR Reporting economic cost, DALYs, social or other burdens, environmental impacts associated with the hazards OR Reporting on aspects of risk factors, knowledge and control methods	From non-target countries Reviews, if they do not contain original field research Published before 1988 (West Africa); Published before 1990 (Uganda) Not written in English (Tanzania, Egypt and Uganda); Not written in English OR French (West Africa)

Table 3. Quality criteria

Good quality	Medium quality ¹	Poor quality
Unbiased selection of subjects	Biased selection of subjects is acknowledged and accounted for	Biased selection of subjects not acknowledged
Data analysis is appropriate	Limitations in data analysis are acknowledged and accounted for	Data analysis is not appropriate
Methods used are scientifically sound	Methods used are scientifically sound, although may not be the most appropriate methods	Wrong or inappropriate methods are used
Accurate description of methods	Some details on methods are lacking, but methods are understandable, and results remain valid	Methods are not clear or incomplete
Reported results are complete and seem accurate		Reported results are incomplete and/or inaccurate

¹Results were considered to be sound and valid, and were therefore extracted.

Table 4. Number of unique records obtained from each database in each of the SRs

Database	Cattle Tanzania	Pigs Uganda	Small ruminants WA	Fish Egypt
Pubmed	94	64	83	12
Cabdirect	109	42	–	121 ¹
Web of Science	113	–	–	56
AJOL	1	3	0	0
Google Scholar	–	–	44	–
Total # hits	317 (224 D)	109 (48 D)	127 (0 D)	189 (8 D)

D, duplicates; – database not used.

¹Includes 54 articles published as proceedings in one publication.

the overall temporal pattern of the published literature in each SR, and the evolution in quality and availability.

Results

Profile, size, and quality of the body of literature

The use of multiple databases helped obtain a comprehensive compilation of the literature. Cabdirect and Web of Science databases gave larger lists of literature in most reviews, but 50% was duplicated when using more than one database. AJOL, an online database specialized in the literature from Africa, did not contribute substantially to the list of articles. In Egypt and West Africa, this database did not contribute any papers, and in Tanzania only 13 articles were found, with virtually all (12 out of 13) already found in the other three databases. Including Google Scholar in the SR for West Africa allowed for inclusion of relevant French literature (1/3 of the overall literature found for West Africa).

Table 4 gives the number of hits obtained in each database for each review, and the number of duplicates.

Figure 2 presents the flowchart for all reviews with details on the number of papers excluded at each step of the review. In most reviews, at least around a quarter of the finally used (i.e. data extracted) publications was not accessible as full text. In Tanzania, overall, 31% (36/115) of the finally selected articles could not be accessed as full paper. Similarly, in Uganda out of the 41 titles considered relevant, only 23 (57.5%) were accessible online as full papers (of which only 8 (20%) were available open access). An additional ten papers were accessible through other sources (i.e. google via European partner VPN), resulting in 83% of the final articles available as full papers. In Egypt, 52% of papers were obtained as full text and in the case of the review in West Africa only 21% of the articles for which data was extracted were available as full text. **Table 5** presents the details of the number of papers that were available either as full papers or as abstracts. Accessibility of full papers did change over time, with less full articles available before 1990 (see **Fig. 1**).

Table 5. Total number of full papers and abstracts selected and the percentage of those rated moderate to good quality for each of the research questions.

SR		Total ¹	Research question			
			Prevalence	Risk factors	Control	Impact
Bovine – Tanzania	Full paper (% quality) ²	102 (77.4)	85 (72.9)	32 (90.6)	26 (92.3)	6 (83.3)
	Abstract	36	23	5	14	1
Pigs – Uganda	Full paper (% quality)	15 (60)	13 (61.5)	3 (33.3)	3 (66.7)	0
	Abstract	2	2	0	0	0
Small ruminants – WA	Full paper (% quality)	12 (85.3)	7 (42.8)	4 (50)	1 ³	0
	Abstract	26	16	5	1	0
Fish-Egypt	Full paper (% quality)	48 (70.8)	36 (63.9)	6 (33.3)	11 ³	1 (100)
	Abstract	33	28	2	1	2

¹Numbers include poor quality papers. Some papers contributed to more than one research question.

²Number papers rated as having good or medium quality*100/total number of papers reviewed.

³Quality not assessed.

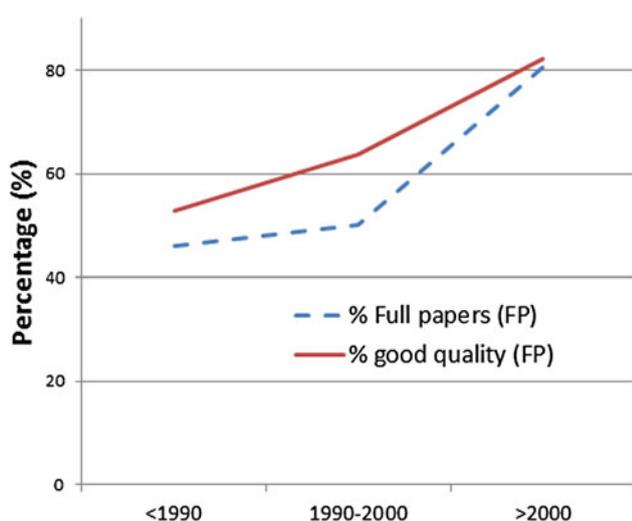


Fig. 1. Proportion of full papers, and good quality full papers by year of publication (Tanzania and Egypt SRs).

The quality assessment of full papers further excluded many articles. In Tanzania, 23 out of 102 full papers (22.6%) were excluded due to poor quality, and in Uganda poor quality papers were 40% of the total number of reviewed papers (Table 5). For half of the rejected papers, inadequate methods (or the use of methods considered not sound) to estimate prevalence, or undertake risk factor analysis, was the reason for rejection. In the other cases, rejection was down to simply the inability to reliably extract data, or even to judge the soundness of the study design, due to poor or incomplete reporting of methods or results. We found the quality of papers improved over time (Fig. 1).

Hazards and distribution over time

We found substantial differences in the amount of literature available for the different research questions. The outcome of all reviews showed that most studies had focused on investigating the presence and/or estimating the prevalence of hazards, followed by studies that attempted to elucidate risk factors associated with the hazards. The amount of studies investigating

impacts or presenting control options was much limited (Table 5). Moreover, the SRs revealed a very heavily skewed distribution of the literature among the selected hazards (Table 6). In Tanzania, most of the scientific work has focused on three infections of cattle: *Brucella* spp., *Mycobacterium* spp. and *Trypanosoma* spp. In the review in West Africa, most literature had focused on Rift Valley fever, associated with important losses in small ruminants. In the case of fish, heavy metals were the most studied hazards. These were also the hazards for which research was found around control and impacts.

The availability of literature and its focus evolved over time. In Uganda, little research on pig-associated zoonoses was found, and this was exclusively linked to *Trypanosoma* spp. until 2000, when research started touching on a larger range of zoonotic hazards (Fig. 3). Similarly, in Tanzania, while the research work has always been dominated by the three cattle infections mentioned above, other pathogens, primarily foodborne zoonotic agents, started to feature from the 1990s. In West Africa, Rift Valley fever research continued to dominate over other hazards (Fig. 3).

Discussion

We conducted SRs for a selection of zoonotic hazards in four different LVCs in four regions in Africa. None of the research questions addressed a specific intervention, and therefore did not follow precisely the PICO format described by O'Connor *et al.* (2014). Instead, the questions aimed at gathering data and information on different aspects of relevance to public health (prevalence, risk factors, control and impact), and were phrased so as to allow retrieval and selection of publications on various hazards and on various livestock value chains. Although these questions, compared with intervention questions, require a less structured approach to selection and data extraction, these are comparable with the approaches preferred to answer public health questions (Jackson and Waters, 2004). Each review also targeted a large number of hazards, partly because of the anticipated limited availability of research on the subject. This increased the workload as it required the preparation of separate data extraction files for each of the research questions, and needed targeted discussions within the review team to standardize the types of data extraction for each question.

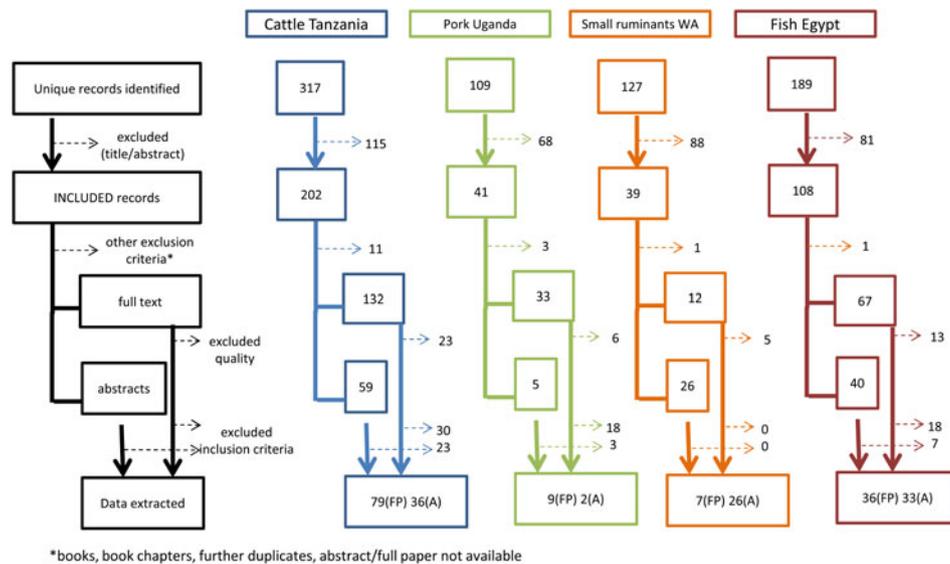


Fig. 2. Flowchart of the review process for each SR, including numbers screened-in and out at each step of the SR.

The quality of the research was variable. Often poor quality was the result of a poor study design, which brought into question the reliability of the results. However, papers were also judged of poor quality when incomplete reporting of information in the manuscript prevented data extraction. Suboptimal reporting of research precludes appropriate use of the research findings and standard publication checklists are increasingly being developed to support rigorous reporting for research work and results (e.g. STROBE statement, Vandembroucke *et al.*, 2007).

Each review was conducted by different teams (only the Tanzania and Egypt review teams included the same reviewers) at different geographical and institutional locations, and therefore access to literature databases and full texts was determined by the degree of access to international literature of the team. The use of various databases was important to obtain a comprehensive compilation of the literature, but the degree of duplicated literature among databases was substantial. Surprisingly AJOL did not contribute many additional hits to the reviews. A challenge commonly faced by African institutions is access to full papers and open access databases of scientific literature. While PubMed and AJOL are open access databases, Cab Direct and WoS require paid registration. In Tanzania and Egypt respectively, 70 and 93% of articles were obtained through these two databases. The team conducting the review in Uganda lacked institutional access to WoS, while the one in West Africa lacked also access to CabDirect, which meant some relevant articles were probably omitted. Even with institutional access to the databases, it may not be possible for researchers in developing countries to access full papers. The number of scientific journals to which research institutions in Africa subscribe to it is likely to be variable across institutions, but, considering how costly these can be, it is also likely to be substantially smaller than the average number of subscriptions held by institutions in, for example, Europe or the USA (Musakali, 2010; Kebede *et al.*, 2014; Karsten and West, 2016). This explains why the proportion of full papers for Tanzania and Egypt (reviews

conducted by ILRI, an international research institute with access to a larger number of journals) is higher than the proportion for West Africa. If African universities do not have a budget for journal subscriptions or purchase of articles, access to international and high-quality scientific literature is limited. Although scientists may access abstracts, these are not an adequate source of scientific information, as they often lack relevant details on study design and characteristics, and do not allow for quality assessment of the research. The need for full paper retrieval is particularly important considering the amount of literature in our review that was judged to be of poor quality. This represents one of the biggest barriers to promoting the dissemination of scientific knowledge and hinders the capacity of African institutions to influence policy through science. To increase the capacity of African institutions to benefit from published research, the burden associated with subscription fees should be alleviated. The practice of levying subscription fees to institutions within such countries, applied by some international journals, should be encouraged broadly. Also publication of research outputs in open access journals should be facilitated and promoted within the global scientific community.

Literature was overall scarce on the selected zoonotic hazards. The review that produced the largest amount of literature was that for cattle production in Tanzania and this may be explained by the role and importance of this production system in this country and region. Tanzania is traditionally a cattle keeping community, with beef and dairy as the largest livestock sectors (MLFD, 2010). This could justify large research efforts and investments in this sector, both nationally and by the international scientific community. On the contrary, pig production in Uganda has only just emerged, with pig production increasing exponentially since the 1990s (FAOSTAT²) and per capita

²FAOSTAT. Annual average of live pigs in Uganda 1970–2014. <http://faostat3.fao.org/browse/Q/QA/E>; accessed February 2016)

Table 6. Number of papers selected for each pathogen, including poor quality papers

		Prevalence/ risk factors		control/ impact		Prevalence/ risk factors		Control/impact		
Pigs Uganda	FB (NZ)	Antibiotic residues	1(F)			West Africa	FB	<i>Salmonella</i> spp.	1(A)	
	FB Z and FB	<i>Ascaris suum</i>	1(F)			Small ruminant	Z and FB	<i>Escherichia coli</i>	1(A)	
		<i>Taenia solium</i> , larval	1(F)					<i>Trypanosoma</i> spp.	1(F)	1(F)
		<i>Trichuris suis</i>	1(F)					Rift Valley fever virus	6(F)	17(A)
		<i>Mycobacterium</i> spp.	7(F)					<i>Chlamydia</i>	1(F)	1(A)
		<i>Trypanosoma</i> spp.	6(F)	1(A)	2(F)		Z and FB	Helminths	3(F)	3(A)
								<i>Brucella</i> spp.	1(F)	
Bovine Tanzania	FB (NZ)	<i>Salmonella typhi</i>	1(F)			Fish Egypt	FB (NZ)	<i>Coxiella burnetii</i>	1(F)	
		Mycotoxins		1(A)				PCB residues	3(F)	2(A)
								Pentachlorophenol (PCPs)/ organochlorines	3(F)	2(A)
		Antibiotic residues	3(F)		1(F)			Mercury	6(F)	5(A)
	FB	<i>Campylobacter</i> spp.	3(F)					Cadmium	21(F)	9(A)
		(Toxigenic) <i>E. coli</i>	5(F)	1(A)				Lead	19(F)	11(A)
		<i>Salmonella</i> spp.	3(F)	1(A)				Other heavy metals	16(F)	7(A)
		<i>Staphylococcus</i> spp.	5(F)	4(A)				Other and undefined pesticides	3(F)	2(A)
							FB	<i>Salmonella</i> spp.	1(F)	2(A)
		<i>Bacillus cereus</i>	2(F)					<i>Vibrio</i> spp.; <i>Vibrio parahaemolyticus</i>	1(F)	3(A)
		<i>Cryptosporidium</i> spp.	6(F)	1(A)				<i>Staphylococcus aureus</i>	1(F)	6(A)
		<i>Toxoplasma gondii</i>	3(F)							
	Z and FB	<i>Trypanosoma</i> spp.	13(F)	5(A)	13(F)	14(A)				
		<i>Mycobacterium</i> spp.	24(F)	4(A)	7(F)					
		<i>Brucella</i> spp.	19(F)	5(A)						
	Rabies virus	1(F)								
	<i>Bacillus anthracis</i>	1(F)	1(A)	1(F)						
	Rift Valley fever virus	5(F)		3(F)						
	<i>Coxiella burnetii</i>	2(F)								
	<i>Leptospira</i> spp.	5(F)	3(A)							

A, abstract; F, full paper; Z, zoonotic; FB, foodborne; NZ, non zoonotic.

Some papers contributed to more than one research question. Hazards for which no abstracts or full papers were selected are not presented in the table.

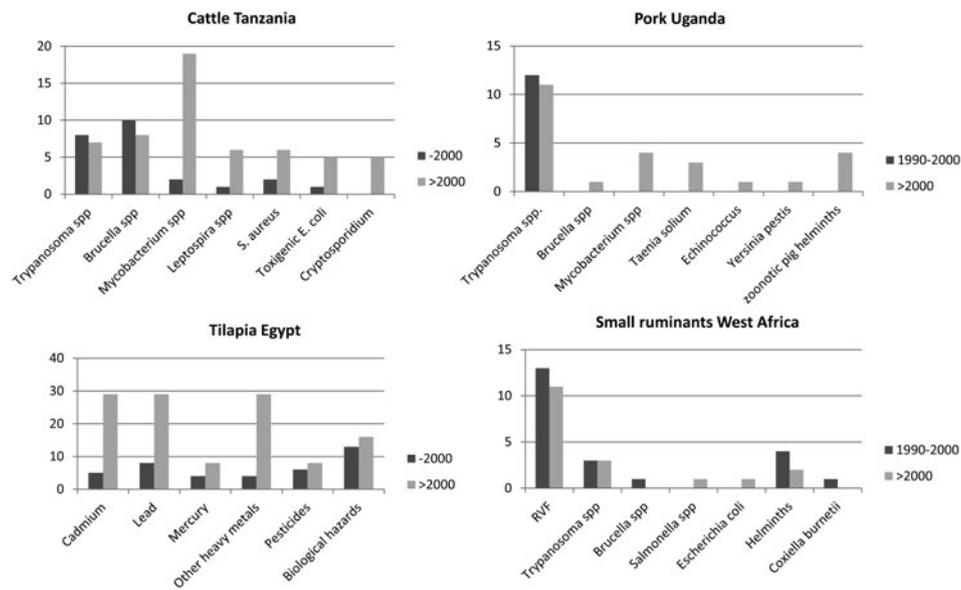


Fig. 3. Temporal distribution of the literature by hazard for each SR (number of articles selected and rated from moderate to good quality, by year of publication).

consumption of pork being the highest in East Africa (ILRI *et al.*, 2011). However, pig keeping is not yet considered a priority on the governments' agricultural agenda, which may explain the little attention received by this value chain from the scientific community. Interestingly, the tilapia value chain is among the oldest and most important food systems in Egypt (El-Sayed, 2006). Egypt is an important tilapia producer, with 12% of the global production in 2002, and the largest producer in Africa and the Near East region (El-Sayed, 2006; FAO, 2006) and yet there was little available literature on zoonotic hazards related to this food product. Considering that in Egypt tilapia is mainly produced for the domestic market (Macfadyen *et al.*, 2012), a body of scientific literature may exist in local scientific journals, which are often not indexed in international databases, and are therefore not accessible to the broadest scientific community. The case is similar for research in West Africa; in our review, including searches in French was key to obtaining literature, with 35% of the included papers exclusively published in French. When conducting SRs on matters of relevance to low-income countries, it is important to not only ensure targeted searches in all relevant languages, but also screening the literature available in national journals, in order to obtain the most comprehensive collation of literature.

Our results show that research in these LVC-countries has been selective, with a few prominent hazards studied more extensively than others. In Uganda, the main researched zoonoses in pigs have been trypanosomiasis followed by *Taenia solium* cysticercosis. Uganda is a hotspot for human African trypanosomiasis, or sleeping sickness (both forms Gambiense and Rhodesiense) and has therefore always been a prominent disease. With pigs being a potential reservoir, this livestock species has often been included in *Trypanosoma* screenings in livestock. *Taenia solium* cysticercosis, especially due to the potential long-term impact on humans (i.e. epilepsy), has been listed as a

neglected tropical disease by the WHO, and research increased largely over the past two decades. Other potential pork-borne zoonotic agents of potentially greater health burden, such as *Salmonella* spp., enterotoxigenic *Escherichia coli* and *Mycobacterium* spp. have only recently been added to the research agenda.

In Tanzania and West Africa, we found an emphasis on infectious agents associated with livestock production constraints rather than exclusive zoonotic risk. In West Africa, most research on small ruminants has focused on Rift Valley fever, a zoonosis associated with hemorrhagic fever in human beings and one of the most devastating diseases of sheep and cattle herds in Africa (Pepin *et al.*, 2010). The disease is often considered an emerging infectious disease with potential for spreading to Europe or America (Chevalier *et al.*, 2010). First reported in East Africa, reports of this disease in West Africa are more recent, with large outbreaks occurring from 1987 and onwards (Nanyingi *et al.*, 2015), resulting in major economic losses. It is therefore possible that it has been relatively easy to attract funding for studying this disease compared with endemic diseases with less notorious impacts. In Tanzania, *Brucella* spp. and *Mycobacterium* spp. have always featured prominently in the literature. These organisms are present worldwide and have historically been among the most important production threats and zoonoses. They have been, and still are, the focus of control efforts throughout the world and it is therefore not surprising that most research has put the focus on these diseases. Trypanosomiasis is also one of the most devastating and most studied bovine diseases in Africa. From the beginning of the 20th century, trypanosomiasis has been the focus of research efforts of the veterinary community in Africa, and large amounts of research funding have been destined to fight this major vector-borne disease (de Raadt, 2005; Steverding, 2008). This too explains why this is the only hazard for which we found scientific literature investigating control and impact.

However, as in the case of Uganda, these zoonoses may not be the most important from a public health perspective. Interestingly, the recent report by the FERG estimated that in the East Africa sub-region, which includes Tanzania, non-typhoidal salmonellosis has a burden of 1.9 million DALYs while brucellosis has a burden of 3225 DALYs (WHO, 2015). In the literature published on tilapia value chain in Egypt, it is clear that chemical hazards (especially heavy metals) are more studied than biological hazards, despite the fact that the health impacts of biologic hazards in fish are likely higher than the impacts of heavy metals (WHO, 2015).

It is clear that governments, media and the agendas of donors can substantially shape the priorities for research, especially in developing countries. As argued by Blench (2000), the International Livestock Centre for Africa (ILCA), operating in Africa from 1974 to 1994, excluded research on pigs likely driven by prejudices from potential donor agencies and the perceived competition between pigs and humans for food (Blench, 2000). Our study seems to suggest that most of the focus of research on the livestock value chains has been placed on production threats and diseases associated with historically important public health impacts. The increasing literature in all countries from the 1990s on other zoonotic pathogens (i.e. foodborne) for which livestock are a healthy reservoir suggests a shift in priorities, and represents a step forward towards the widely promoted One Health approach to research and policy (Welburn *et al.*, 2015). In the years following this review (2013 to today) zoonotic pig diseases are more researched in East Africa; 29 original research articles have been published since then covering the role of pigs in zoonoses, including pork-borne infectious diseases such as enterotoxigenic *E. coli*, salmonellosis, *Taenia solium* cysticercosis, tungiasis and Ebola (potentially pork-borne, but not yet proven), among others (data not shown). Other likely important pig zoonoses such as trichinellosis and campylobacteriosis are still under-researched.

Policy-oriented research must be able to answer policy questions. Understanding disease risk and impact is crucial to setting priorities, allocating public funds and discussing trade-offs. Veterinary public health research has focused on assessing the presence of hazards and, to a limited extent, on identifying risk factors for infection. Solid risk factor analysis is still a big challenge in developing countries where data on etiologic agents of disease outbreaks both in humans and animals as well as structured disease reporting is scarce. Policy makers in developing countries require a more comprehensive understanding of zoonotic hazards and local health risks to be able to formulate actionable and effective policy measures. Our SRs found that research on disease impact, management and mitigation of zoonotic risks is worryingly lacking. Ultimately, this impedes prioritization of public health problems and the utilization of scarce resources in the most effective way (Roesel and Grace, 2014).

Conclusion

The ability to undertake SRs on veterinary public health in livestock systems in Africa is compromised by limited availability

and accessibility of the literature. High quality research should be promoted. More research is needed on livestock and public health issues, with an emphasis on zoonotic pathogens that are sub-clinically carried by livestock, but that cause a significant health burden in people. Also, research on disease impacts and control is especially lacking, and should be made a priority.

Accessibility of the literature is a major constraint for African research institutes and individuals. It is therefore imperative that research on topics of relevance to low-income countries is published in open access journals. Greater efforts could be made to have more comprehensive open-access, web-based African repositories of research literature on topics of relevance to Africa. Even though this work focused on Africa, the same situation is likely to apply in many other low-income countries and, similarly, efforts should be made to provide access to journals and databases globally.

Supplementary material

The supplementary material for this article can be found at <http://dx.doi.org/10.1017/S1466252316000104>.

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References

- Alonso S, Dohoo I, Lindahl J, Verdugo C, Akuku I and Grace D (2016). Prevalence of tuberculosis, brucellosis and trypanosomiasis in cattle in Tanzania: a systematic review and meta-analysis. *Animal Health Research Reviews*. doi:10.1017/S146625231600013X.
- Blench RM (2000). A history of pigs in Africa. In: Blench RM and MacDonald KC (eds). *The Origins and Development of African Livestock. Archaeology, Genetics, Linguistics and Ethnography*. United Kingdom: UCL Press, pp. 355–367.
- Chevalier V, Pépin M, Plée L and Lancelot R (2010). Rift Valley fever – a threat for Europe? *Euro Surveillance: Bulletin Européen sur les Maladies Transmissibles = European Communicable Disease Bulletin* **15**: 30–40.
- Cutler SJ, Fooks AR and Van Der Poel WHM (2010). Public health threat of new, reemerging, and neglected zoonoses in the industrialized world. *Emerging Infectious Diseases* **16**: 1–7.
- de Raadt P (2005). The history of sleeping sickness. In *Fourth International Course on African Trypanosomoses*.
- El-Sayed A-FM (2006). *Tilapia Culture*. United Kingdom: CABI.
- FAO (2006). *Regional Review on Aquaculture Development 2. Near East and North Africa – 2005*. Rome, Italy: FAO Fisheries Circular No. 1017/2.

- FAO (2014). *Business and Livelihoods in African Livestock: Investments to Overcome Information Gaps*. Washington, USA: World Bank Publications.
- Gopalakrishnan S and Ganeshkumar P (2013). Systematic reviews and meta-analysis: understanding the best evidence in primary health-care. *Journal of Family Medicine and Primary Care* **2**: 9–14.
- Grace D, Mutua F, Ochungo P, Kruska R, Jones K, Brierley L, Lapar L, Said M, Herrero M, Phuc PM, Thao NB, Akuku I and Ogutu F (2012a). Mapping of poverty and likely zoonoses hotspots. Report for DFID, United Kingdom, 1–119.
- Grace D, Gilbert J, Randolph T and Kang'ethe E (2012b). The multiple burdens of zoonotic disease and an Ecohealth approach to their assessment. *Tropical Animal Health and Production* **44** (suppl. 1): S67–S73.
- Halliday JE, Allan KJ, Ekwe D, Cleaveland S, Kazwala RR and Crump JA (2015). Endemic zoonoses in the tropics: a public health problem hiding in plain sight. *Veterinary Record* **176**: 220–225.
- Herrero M and Thornton PK (2013). Livestock and global change: emerging issues for sustainable food systems. *Proceedings of the National Academy of Sciences of the United States of America* **110**: 20878–20881.
- ILRI (2012). Mapping of poverty and likely zoonoses hotspots. Zoonoses Project 4. Report to Department for International Development, UK, p. 119 pp.
- ILRI, CIAT, ICARDA and WorldFish Center (2011). Smallholder pig production and marketing value chain in Uganda: Background proposals for the CGIAR Research Program on Livestock and Fish. Nairobi, Kenya.
- Jackson N and Waters E (2004). The challenges of systematically reviewing public health interventions. *Journal of Public Health (Oxford, England)* **26**: 303–307.
- Karsten J and West DM (2016). The impact of open access scientific knowledge. *TechTank. Improving Technology Policy*. Available at: <http://www.brookings.edu/blogs/techtank/posts/2016/01/11-open-access-scientific-knowledge> [Accessed April 12, 2016].
- Kebede D, Zielinski C, Mbondji PE, Sanou I, Kouvidila W and Lusamba-Dikassa PS (2014). Institutional facilities in national health research systems in sub-Saharan African countries: results of a questionnaire-based survey. *Journal of the Royal Society of Medicine* **107**(1 suppl.): 96–104.
- Macfadyen G, Nasr-Allah AM and Dickson M (2012). *The Market for Egyptian Farmed Fish*. Penang, Malaysia: WorldFish.
- Meslin FX, Stöhr K and Heymann D (2000). Public health implications of emerging zoonoses. *Revue Scientifique et Technique (International Office of Epizootics)* **19**: 310–317.
- MLFD, M. of L. and F.D. (2010). *Livestock Sector Development Strategy*. Dar es Salaam, Tanzania: Ministry of Livestock and Fisheries Development.
- Moher D, Liberati A, Tetzlaff J and Altman DG (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine* **151**: 264–269, W64.
- Musakali JJ (2010). Continent needs strong ICT policies. *Business Daily*. Available at: <http://www.businessdailyafrica.com/Opinion-and-Analysis/-/539548/838120/-/4khtj/-/index.html> [Accessed April 12, 2016].
- Nanyingi MO, Munyua P, Kiama SG, Muchemi GM, Thumbi SM, Bitek AO, Bett B, Muriithi RM and Njenga MK (2015). A systematic review of Rift Valley Fever epidemiology 1931–2014. *Infection Ecology & Epidemiology* **5**.
- O'Connor AM, Anderson KM, Goodell CK and Sargeant JM (2014). Conducting systematic reviews of intervention questions I: writing the review protocol, formulating the question and searching the literature. *Zoonoses and Public Health* **61** (suppl. 1): 28–38.
- Pepin M, Bouloy M, Bird BH, Kemp A and Paweska J (2010). Rift Valley fever virus (Bunyaviridae: Phlebovirus): an update on pathogenesis, molecular epidemiology, vectors, diagnostics and prevention. *Veterinary Research* **41**: 61.
- Petticrew M (2001). Systematic reviews from astronomy to zoology: myths and misconceptions. *BMJ (Clinical research ed.)* **322**: 98–101.
- Popay J, Rogers A and Williams G (1998). Rationale and standards for the systematic review of qualitative literature in health services research. *Qualitative Health Research* **8**: 341–351.
- Roesel K and Grace D (2014). Food safety and informal markets: animal products in sub-Saharan Africa. London: Routledge.
- Sargeant JM and O'Connor AM (2014a). Conducting systematic reviews of intervention questions II: relevance screening, data extraction, assessing risk of bias, presenting the results and interpreting the findings. *Zoonoses and Public Health* **61** (suppl. 1): 39–51.
- Sargeant JM and O'Connor AM (2014b). Introduction to systematic reviews in animal agriculture and veterinary medicine. *Zoonoses and Public Health* **61** (suppl. 1): 3–9.
- Sargeant JM, Rajic A, Read S and Ohlsson A (2006). The process of systematic review and its application in agri-food public-health. *Preventive Veterinary Medicine* **75**: 141–151.
- Schelling E, Grace D and Willingham AL 3rd RT (2007). Research approaches for improved pro-poor control of zoonoses. *Food and Nutrition Bulletin* **28**(2 suppl.): S345–S356.
- Steverding D (2008). The history of African trypanosomiasis. *Parasites & Vectors* **1**: 3.
- Thornton PK (2010). Livestock production: recent trends, future prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences* **365**: 2853–2867.
- Vandenbroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, Poole C, Schlesselman JJ, Egger M and STROBE Initiative (2007). Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Medicine* **4**: e297.
- Welburn SC, Beange I, Ducrot MJ and Okello AL (2015). The neglected zoonoses—the case for integrated control and advocacy. *Clinical Microbiology and Infection* **21**: 433–443.
- WHO (2015). *WHO Estimates of the Global Burden of Foodborne Diseases: Foodborne Disease Burden Epidemiology Reference Group 2007–2015*. Geneva, Switzerland: World Health Organization.