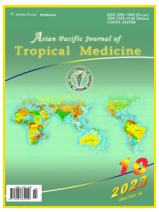

Review Article

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South Asian dairy smallholders: A scoping review of practices and zoonoses

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ABSTRACT

Objective: To identify and discuss on-farm management practices linked to bacterial zoonosis risk in smallholder dairy farmers in South Asia.

Methods: This scoping review was conducted as per the PRISMA-ScR guidelines. Five hundred and two publications were retrieved from five online databases using a comprehensive search strategy. Studies were selected if they discussed a farm management practice which impacted human health within a South Asian country.

Results: Twenty-two studies were included. Seven management practices relevant to farmers, livestock and their shared environment were identified including raw milk consumption, farm hygiene management, personal protective equipment uses, animal vaccination, cleaning udders, hand washing and disposal of afterbirth materials. Preventive practices were found to be utilized at lower frequencies compared to risk increasing practices. Awareness of bacterial zoonoses is particularly low within the region.

Conclusions: Based on the results of this review, it was determined that improving farmer awareness of bacterial zoonotic diseases may favor several of the presented leverage points within the South Asian smallholder dairy system. Relying on formal school education to improve this awareness may not solve this problem, instead, more focus on accessible and affordable zoonoses education and farming programs is required.

KEYWORDS: Management practices; Zoonoses; Dairy; Smallholder system

1. Introduction

Strengthening small-scale agricultural systems is essential to create food and income security. Dairy smallholders, defined as an agricultural holding of up to 20 milking cows, underpin the South Asian milk value chain, which accounts for 20% of global milk production[1,2]. The dairy smallholder sector has been an important supplier to the steady increase in dairy consumption over the last three decades driven by fast population growth in the region[3].

Growth in the South Asian dairy sector has created new animal-human interfaces, especially in peri-urban areas where human and livestock densities are high[4]. Smallholder dairy systems are often characterized by poor biosecurity and infection control that facilitates the spread of infectious diseases among animals, and from animals to humans[5,6]. Bacterial zoonoses like brucellosis, bovine tuberculosis, and leptospirosis may spread and persist in these

Significance

The South Asian dairy sector has experienced exponential growth which has driven smallholder dairy production, facilitating the rise in the risk of zoonotic transmission. Our scoping review sought to uncover '*what on-farm management practices reduce or increase the risk of bacterial zoonoses in smallholder dairy farmers in South Asia*.' We identified seven practices that can be addressed with low-cost interventions, resulting in the prevention of multiple bacterial zoonoses in the region. Our findings also suggest that education to improve farmer awareness of zoonoses is critical to inflict sustainable change in smallholder dairy systems.

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systems, with negative effects on animal health and productivity, and threatening chronic illness and death among stakeholders of the milk value chain[6]. People acquire bacterial zoonoses by direct contact with infected animals and their environment, or *via* consumption of contaminated animal-sourced products such as raw milk[7,8].

On-farm practices, including farmers' personal safety practices, management and interaction with animals, animal products and their shared environment, have direct effects on the emergence, persistence and spread of bacterial zoonoses in smallholder dairy systems. This review collates and describes the role of such practices in bacterial zoonosis dynamics, providing important information to identify on-farm management practices linked to bacterial zoonosis risk in smallholder dairy farmers in South Asia that could be used to inform future mitigation.

2. Materials and methods

We conducted a scoping review following the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines[9] to answer the following research question: *What on–farm management practices reduce or increase the risk of bacterial zoonoses in smallholder dairy farmers in South Asia?*

2.1. Search strategy

A comprehensive search strategy was developed to explore available literature across five online databases, CAB Direct, Web of Science, Scopus and PubMed allowing access to MEDLINE, which were selected based on their specialization in the human-animal interface.

The search strategy comprises seven search strings describing location, dairy species, animal husbandry practices, dairy farming, and disease. We did not restrict the search to specific bacterial zoonoses to minimize the risk of excluding relevant studies. The search includes studies published between 1990 and 2022 due to the increase in smallholder dairy consumption and production observed during this period[3]. The most recent database search was conducted on the 29th of March 2022, and included terms were listed below:

("South Asia" OR "south asian" OR India OR Pakistan OR Bangladesh OR "Sri Lanka" OR Afghanistan OR Nepal OR Bhutan OR Maldives) AND (zoono*) AND (buffalo OR cattle OR cow OR goat OR sheep OR camel OR livestock) AND (procedure OR farming OR farmer OR husbandry OR practice OR management) AND (Dairy OR milk OR milking OR dairies OR dairying) AND (Control OR prevent* OR disease OR "risk factors" OR risk OR spread OR infect*) AND yr: [1990 TO 2022].

2.2. Eligibility criteria

Studies eligible for this review were peer-reviewed articles published in English, between years 1990 and 2022, which reported smallholder systems in South Asia and had a focus on on-farm practices (preventative or risky) associated with bacterial zoonoses. Studies that did not discuss zoonotic potential of bacterial diseases, and instead analyzed the prevalence, incidence, sero-prevalence or genomic details of these diseases on animal populations only, were excluded. Studies conducted on large-scale commercial dairy farms, conference abstracts, and zoonoses reports that did not target South Asian smallholders were excluded. Review articles were excluded, but their reference list was screened to identify relevant articles potentially missed by our search strategy. Non-peer reviewed or gray literature was not considered for this review.

2.3. Data management and extraction

Articles retrieved were imported into Covidence[10] for de-duplication, screening and full-text review. Articles were primarily screened by Emily Schembri, with support from Angus JD Campbell and Juan Pablo Villanueva-Cabezas. The final selection of articles was confirmed by all co-authors. From the studies, the following data were extracted into a data charting form in Microsoft Excel: author, publication year, country, study design, study population, setting, practices and outcome measures. The quality of these studies was assessed using the Joanna Briggs Institute (JBI) tools[11]. Study outcomes were grouped according to their relevance to any of the three domains (human, animal and environment) of One Health, and then conceptualized through construction of an influence diagram using system thinking principles[12].

3. Results

3.1. Study selection

Five hundred and two studies were retrieved and imported into Covidence[9] for de-duplication and screening. The titles and abstracts of 317 unique studies were screened; 232 did not meet the eligibility criteria. Next, 85 studies were scrutinized in full-text; 61 studies were excluded with reasons, and full-text was unavailable for another two. Finally, 22 studies were included in this review (Figure 1).

3.2. Study characteristics

Most studies were conducted in India (n=14), followed by Pakistan and Bangladesh (n=3), Nepal and Afghanistan (n=1). All included

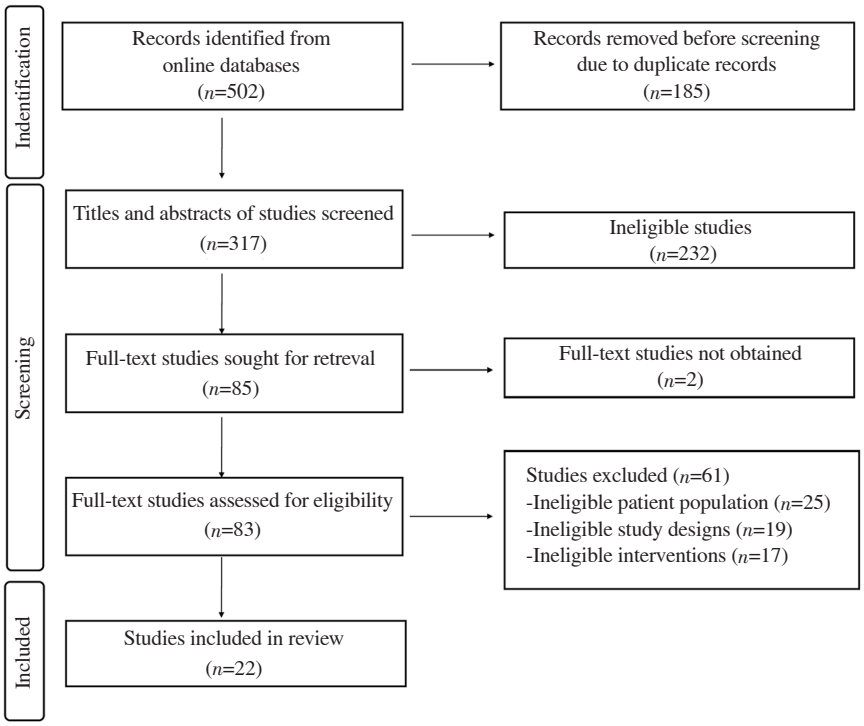

Figure 1. PRISMA flowchart for the study selection process.

studies were observational, comprising 21 cross-sectional studies, including questionnaires (n=13) and seroprevalence surveys paired with questionnaires (n=8), and one case-control study. Most studies focused on five bacterial zoonoses: brucellosis[13–25], bovine tuberculosis[21,24,26–28], leptospirosis[29], Q Fever (coxiellosis)[13], and anthrax[21]. Five studies reported unspecified bacterial zoonoses[30–34] (Table 1). Studies were critically appraised using the JBI tools[11]; most studies considered small samples and relied on the self-reporting nature of questionnaires or surveys, which may result in recall bias. A summary of this appraisal is presented in Supplementary Tables.

3.3. On-farm practices

Seven on-farm practices associated with bacterial zoonotic infection risk in humans were identified: raw milk consumption, use of personal protective equipment (PPE), hand washing, animal vaccination, cleaning udders, disinfecting farming areas, and appropriately disposing of afterbirth materials. Of these, raw milk consumption was identified in more than half of the studies as being practiced by farmers[13–16,18–20,22–28,32,33]. It was the only reported practice associated with an increased risk of zoonosis transmission, and was specifically reported in the context of brucellosis and bovine tuberculosis infection. In contrast, other practices were preventative, but were reported as performed by farmers in low frequencies: use of PPE[15,22,23,25,27,31–33], animal vaccination[16,17,22,23,25,32], cleaning udders[31,33,34], and appropriately disposing of afterbirth materials[13,22,25]. Preventative practices performed at high frequencies included disinfecting farm areas[13,15,16,22,27,33,34], and hand washing[13,24,27,31–33]. Where reported, these practices were associated with brucellosis, bovine tuberculosis, and leptospirosis infection.

Over half of the studies reported limited zoonosis awareness among farmers. Farmers frequently could not name zoonoses they were at risk of acquiring[15–17,19,21–24,27–29,33], their transmission routes[15,17,21,22,24,27,29,33], signs and symptoms[15,17,21,22,24,27,29]. Studies also reported minimal knowledge of preventive practices[15,17,22,24,27,29–31,33] and risk increasing practices[15,17,22,24,27,29–31].

3.4. Practices in a One Health context

The on-farm practices identified were classified into the traditional One Health domains as follows: (1) Farmer management practices (human domain): Use of PPE, hand washing, raw milk consumption; (2) Animal management practices (animal domain): Vaccination of animals, udder hygiene; (3) Environment management practices (environment domain): Farm cleaning and disinfection, appropriate disposal of afterbirth materials.

Figure 2 presents an influence diagram built using systems thinking principle[12], which is a simplified representation of the interconnections among One Health domains used to assist with hypothesis generation of how practices influence an outcome. Under system thinking principles, loops represent leverage points[12]

Table 1. Characteristics of studies retained for review (*n*=22).

References	Study characteristics													Study findings									
	Bacterial zoonoses						Country					Study design		Frequency of awareness reported			Frequency of practice use						
	Brucellosis	Bovine tuberculosis	Q Fever	Leptospirosis	Anthrax	Unspecified	India	Pakistan	Bangladesh	Nepal	Afghanistan	Cross-sectional	Case-controll	Zoonotic disease	Risky practices	Preventative practices	Raw milk consumption	Animal vaccination	Udder hygiene	Disposal of afterbirth	Farm disinfection	Hand washing	PPE use
Akbarian *et al.*[13]	X		X								X	X					X			X	X	X	
Ali *et al.*[14]	X							X				X					X						
Deka *et al.*[15]	X						X					X		X	X	X	X				X		X
Holt *et al.*[16]	X						X					X		X			X	X			X		
Hussain *et al.*[17]	X							X				X		X	X	X		X					
Mangtani *et al.*[18]	X						X					X					X						
Nawaz *et al.*[19]	X							X				X		X			X						
Rahman *et al.*[20]	X								X			X					X						
Rajput *et al.*[21]	X	X			X		X					X		X									
Saidu *et al.*[22]	X						X					X		X	X	X	X	X		X	X		X
Sikder *et al.*[23]	X								X			X		X			X	X					X
Singh *et al.*[24]	X	X					X					X		X	X	X	X					X	
Yadav *et al.*[25]	X						X					X					X	X		X			X
Gompo *et al.*[26]		X								X			X				X						
Islam *et al.*[27]		X							X			X		X	X	X	X				X	X	X
Lakra *et al.*[28]		X					X					X		X			X						
Jadav *et al.*[29]				X			X					X		X	X	X							
Ahuja *et al.*[30]						X	X					X			X	X							
Chinchwadkar *et al.*[31]						X	X					X			X	X			X			X	X
Patel *et al.*[32]						X	X					X					X	X				X	X
Singh *et al.*[33]						X	X					X		X		X	X		X		X	X	X
Singh *et al.*[34]						X	X					X							X		X		

PPE: personal protective equipment.

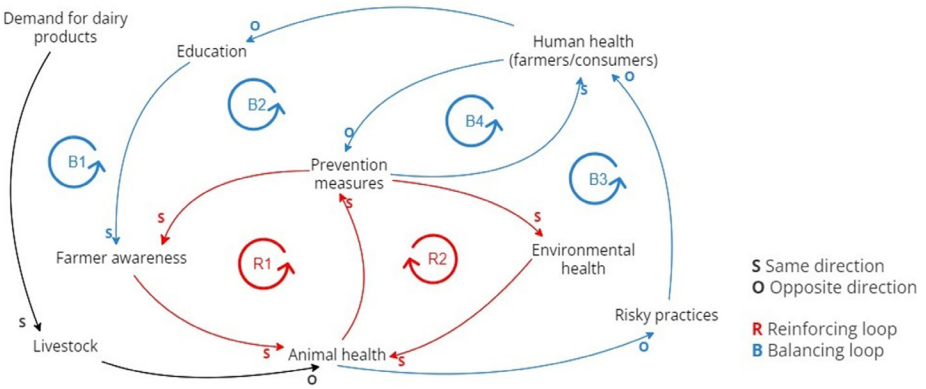

Figure 2. Influence diagram of practices associated with bacterial zoonoses reported in reviewed studies of South Asian smallholder dairy systems. Farmer's awareness is hypothesized to contribute to two reinforcing loops (R1, R2) that can sustain multiple co-benefits in the system over time.

that facilitate the achievement of positive synergistic effects that maximize co-benefits across One Health sectors[35]. These key leverage points within our system are shown by two reinforcing loops presented in red: R1 (farmer awareness; animal health; prevention measures) and R2 (animal health; prevention measures; environmental health), which counteract the action of four balancing loops presented in blue: B1 (education; farmer awareness; animal health; risky practices; human health), B2 (farmer awareness; animal health; prevention measures; human health; education), B3 (animal health; risky practices; human health; prevention measures; environmental health) and B4 (human health; prevention measures). The black pathway presents external factors influencing the system. We hypothesize that education specifically focused on improving farmer awareness of zoonotic bacterial diseases may favor leverage points associated with two reinforcing loops, reducing effects derived from the balancing loops identified in this system.

4. Discussion

On-farm practices have direct effects on the emergence, persistence and spread of bacterial zoonoses in any dairy system. This review has systematically described practices that can be associated with the spread or prevention of bacterial zoonosis in smallholder systems of South Asia, and presents potential points of leverage for reducing risk of zoonotic disease transmission. Despite the importance of smallholder dairy production in South Asia, the relatively small research effort we report in this sector suggests widespread underrepresentation of studies exploring the risk of exposure to zoonotic diseases in small scale livestock production systems common in low- and middle-income countries. This underrepresentation has been previously highlighted as a major barrier for improved understanding of disease dynamics in these contexts[35].

The bacterial zoonoses identified-brucellosis, bovine tuberculosis, leptospirosis, Q Fever (coxiellosis) and anthrax-represent important neglected diseases common in a wide array of livestock production systems found in South Asia and globally[36]. They range in their mechanisms of impact from predominantly sub-clinical infections in animals such as coxiellosis with important zoonotic consequences, to outbreak diseases like anthrax that cause morbidity and mortality in humans, and substantial economic loss through animal mortality and the costs of control. Despite these diverse epidemiologies, effects and consequences, many of these diseases share some common risk factors and potential methods of mitigation or control of their zoonotic impacts[6].

Mitigation proves challenging as risky practices are generally ingrained within smallholder dairy activities and may be difficult to change[37]. As portrayed in our influence diagram, increasing demand for dairy products increases the livestock population being managed by smallholder farmers. Smallholders frequently experience limited access to resources (*e.g.*, veterinary assistance) which paired with low farmer awareness of zoonoses has likely effects on reduced animal health and wellbeing[38]. In a scenario of poor animal health perpetuated by poor access to preventive or curative resources, risky practices such as inadequate handling or disposal of afterbirth material may facilitate disease transmission between animals and humans[6]. The influence of low farmer awareness on the above pathways, coupled with low levels of animal health may result in unintended risky practices (*e.g.*, milking animals with signs of disease; inadequate management and disposal of afterbirth materials), with direct, adverse effects on reduced farmers' and consumers' health and wellbeing[39]. Thus, education and zoonotic awareness seems critical to reduce risky practices and encourage safe behaviors. Farmer awareness may improve animal health and encourage preventative measures that reinforce farmer awareness and improve human health outcomes. Similarly, preventive measures will also improve environmental health[40] (*e.g.*, reduced pathogen load in farms, shared areas, natural environments) with synergistic effects on livestock, human health, and co-benefits for other organisms (*e.g.*, wildlife) not explicitly represented in this system.

Our scoping review uncovered an overall low level of awareness of bacterial zoonotic diseases in regards to naming, understanding of transmission routes and prevention measures among farmers. We acknowledge that some studies did not disclose questionnaires, thus we are unable to clarify how questions were presented to farmers. Where included, questionnaires used scientific names and technical language. It is likely that farmers are more familiar with colloquial terms and names of zoonotic diseases, as smallholder farmers acquire knowledge based on systems of trust, frequently learning their trade from family and friends, community elders, and personal observations[41,42]. Education programs are particularly effective when these consider the level of poverty, access to health care, animal management infrastructure, religion, local languages and cultural views, as these influence the sustainability of the intervention over time[43-46]. The seven practices identified in this review represent clear, realistic targets for community education programs, as most can be addressed with low-cost interventions, resulting in the co-benefit of preventing multiple bacterial zoonoses in the region including brucellosis, zoonotic tuberculosis, leptospirosis, and anthrax.

Our findings suggest that ensuring consistent farmer awareness through education may result in synergistic positive effects and a series of co-benefits that counteract the effects of a series of balancing loops and the re-emergence of bacterial zoonoses. Ideal community education must encompass One Health as zoonotic risk cannot be reduced without considering animal populations and environments[47-49]. Governments and international agencies have promoted an agenda to incorporate One Health education within veterinary, epidemiology, and public health tertiary degrees in South Asia, increasing One Health research capacities and training programs[50,51]. However, integral approaches to the management of One Health issues, including zoonoses, will benefit from early, inclusive, and holistic training that transcends veterinary and medicine schools[52].

Zoonoses disproportionately affect low-income, livestock-dependent countries, with South Asian dairy farming communities hit particularly hard[4]. Not only is addressing the interconnected nature of this system important for bacterial zoonoses prevention, but also aids in addressing global goals such as the United Nations Sustainable Development Goals that can make a difference[53]. Improving farmer education and awareness will assist in increasing the welfare and productivity of livestock, with positive effects on

livelihoods-food, education, health care, and supporting stronger communities[54].

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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Authors' contributions

J.P. V-C and A.J.D.C. conceptualized the project. E.S., J.P. V-C and A.J.D.C. developed the research plan. E.S led the scoping review under supervision of J.P.V-C and A.J.D.C. All authors contributed to the interpretation of results and final version of the manuscript.

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