Title:

Neglected paths of transmission for milkborne Brucellosis and Tuberculosis in developing countries: Novel control opportunities

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Introduction

Brucellosis and tuberculosis are two important chronic infections that are endemic in many parts of the world especially in developing countries including India. These zoonotic diseases continue to inflict heavy burdens on human morbidity and mortality worldwide and cost staggering amounts for the affected economy [1,2]. Of these, brucellosis, caused by various species of the genus *Brucella*, is a major milkborne zoonotic disease and principally originates in the dairy animals including cattle, sheep and goats. While global cost estimates for brucellosis is hard to come by, available estimate from India indicates a median loss of USD 3.4 billion annually with prevalence upto 12% [2,3]. Tuberculosis, on the other hand, is primarily caused by *Mycobacterium tuberculosis* and *M. bovis*, with evidences suggesting a substantial underestimation of the latter in causing human diseases. *M. bovis* causes extrapulmonary tuberculosis in humans and is predominantly a milkborne zoonosis originating from bovines [1]. Zoonotic tuberculosis is responsible for close to 10% of human tuberculosis cases in developing nations and costs approximately USD 3 billion annually due to production losses to world cattle industry [4]. With a lack of control programme and considerable prevalence (approximately 7.3%) of zoonotic tuberculosis affecting a large number of cattle (approximately 21.8 million) large developing nations such as India pose particular challenges for global efforts for tuberculosis control [4].

The challenges

Pasteurization of milk traditionally remained the mainstay to stem the milkborne spread of brucellosis and tuberculosis. However, with a rising trend of consumption of minimally processed foods and unique marketing modes of milk in developing countries including India, a large section of population thrives on unpasteurized milk supply. Both these zoonotic diseases have been studied in detail over many decades and multiple guidelines for control of these diseases exist. However, we observed certain unattended potential transmission routes which need to be addressed with priority.

In developing countries like India, primary milk production, distribution and marketing are highly fragmented and as noted by Kumar and colleagues [5], about two-thirds of the milk produced in India is actually marketed, of which 75-80% flows through informal, traditional,
unregulated channels. Our experience as public health veterinarians indicated that milk is often produced at multitudes of small farms, small-to-medium sized peri-urban dairies and is distributed unpasteurized to households in the vicinity of the farms through these local channels (Figure 1a). We further noticed that it is a common practice among customers to strain the unpasteurized milk at the receipt to filter out the visible dirt, followed by boiling of milk usually for 5-10 minutes before consumption (Figure 1b-e). While boiling effectively neutralizes/kills milkborne pathogens including \textit{Brucella} and \textit{Mycobacterium}, the strainer is often ignored and is just rinsed in water and is used for other kitchen applications. Moreover, it is common for the customers to receive the unpasteurized milk in one container (usually plastic or glass) and then change the container for boiling of milk, while the first container is reused for other kitchen purposes following casual rinsing with water. We strongly suspect that such practices of straining and change of containers for handling raw unpasteurized milk, create additional fomites which might potentially harbor milkborne pathogens especially, \textit{Brucella} and \textit{Mycobacterium} as they are sturdy survivors in moist ambience and may lead to kitchen cross contamination posing a serious health threat to consumers.

In addition, at the farm level, we find another common practice which is also potentially hazardous, though farm hygiene is considered a major component for control of brucellosis and tuberculosis. Due to small scale dairy production systems in India and other developing countries, machine milking is uncommon and milking is mostly carried out manually at farms. Across dairy farms, it is common among milkers to discard first few strippings of milk before the actual collection to avoid contamination of the entire collection. As the first strippings are usually high in bacterial count, we suspect that this practice significantly increases the floor contamination and may lead to transmission of brucellosis and tuberculosis to farm personnel, other susceptible animals and may contaminate the farm environment. The environment may become contaminated with the discharges (excretions/secretions) of the infected animals which can be picked up by other susceptible animal hosts. A number of reports are available on role of contaminated immediate environment in the transmission of brucellosis and tuberculosis within dairy herds [6 - 8].

The solutions
It is intriguing, that we did not find any mention of these potential routes of disease transmission in commonly available guidelines for brucellosis and tuberculosis control. Considering the hazards, current practices, cultural preferences of consumers, and absence of
appropriate guidance, we propose that retail consumers of raw and unpasteurized milk, abstain from using strainer on receipt of milk and boil the milk in the same container in which the milk was received. If milk supplied is visibly polluted with dirt and straining is necessary, then the strainer should be subjected to boiling in water for at least 10 minutes and rinsed thereafter, before being put to other kitchen uses.

On the practice of discarding of first strippings of milk, we propose that the first stripping should not be discarded on the floor, rather they should be collected in a special vessel with a funnel placed inside (to avoid aerosol formation), containing common disinfectant solution (e.g. 5% phenol, 2% glutaraldehyde, 0.5% sodium hypochlorite, etc.) to inactivate the pathogens (Figure 1f). The collect may safely be disposed off later following established protocol of the farm.

**Education of livestock farmers and consumers for control of zoonotic diseases**

Control of zoonotic diseases rely on active participation by all stakeholders including livestock farmers and consumers alongwith a sustained and scientific approach in awareness building and education [9, 10]. Multiple studies from around the world have highlighted the need for education and awareness building among farmers and consumers for effective alleviation of zoonoses including brucellosis and bovine tuberculosis [11 - 17].

While bringing behavioral changes to combat zoonoses is very effective, achieving the desired behavioral modification through education and awareness is challenging. A number of tools and methods are available for educating farmers which may be utilized for such purposes [18]. Moreover, there is a need for improved risk communication and updated guidelines (incorporating steps that were proposed by us), for early adoption by livestock farmers and consumers. Since optimal health education programme have a significant impact on control of zoonotic diseases, customized training modules on 'Kitchen Hygiene' and 'Dairy Farm Hygiene' focusing the novel control opportunities, proposed in this paper, need to be developed and disseminated for curbing the spread of zoonotic tuberculosis, brucellosis and other similar diseases. Based on our experiences we recommend, effective use of various digital tools (mass/social media) and creative communication channels (e.g. focus group discussion, etc.) to reach marginal livestock farmers, dairy cooperatives and consumers around the world. However, communication materials should be designed in local/ vernacular languages with pictorial presentation of 'unrecognized transmission paths' as well as 'the novel control methods' for greater penetration among the native population. These need to be
supported by advocacy programmes for desirable behavioural modifications. Nevertheless, all these efforts need to be backed by strong political will and adequate funding mechanism for sustenance [9, 10].

Conclusions
It is an established fact that control of any zoonotic infections in humans must start with prevention and control diseases in animal hosts while also ensuring safety of foods of animal origin. Considering our observations and potential solutions proposed, we believe that these simple and practicable measures may provide effective barriers for spread of brucellosis, tuberculosis and also other milkborne zoonotic diseases through hitherto unheeded transmission routes. Building awareness among consumers of unpasteurized milk and milkers for these proposed interventions is therefore essential. Overlooking such unknown yet critical transmission paths might prove costly for control of such important zoonotic diseases which already consumes huge public health funding for their control worldwide.

Ethics statement
Not applicable as the manuscript does not involve any experiment.

Conflict of interest
Authors declare no conflict of interest.

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Author contributions
Conceptualization: AAPM, SD and SG. Writing - original draft: SG, AAPM and SD. Writing - review & editing: SD, SG and AAPM.

References


Figure caption:
Figure 1: Informal retail milk handling by door-step vendors (a), consumers (b-e), and proposed design of a safety container for collecting discarded first stripings in a farm (f)