Acceptability and Feasibility of Proposed Control and Prevention Strategies for Bovine Tuberculosis among Ethiopian Dairy Farmers and Associated Professionals

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Abstract

A series of Focus Group Discussions were held with farmers, veterinarians and human health workers in two sites in Ethiopia, as part of the Ethiopia Control of Bovine Tuberculosis Strategies Project's efforts to devise and test the acceptability and feasibility of various control strategies for Bovine Tuberculosis (bTB). Group members were asked to give their responses to a range of strategies collected from global efforts to control the disease in cattle and humans in the context of intensification of the dairy industry, as well as those suggested by researchers within the project. Key findings from the study include the observation that a number of strategies utilised routinely to control bTB elsewhere in the world, including 'Test and Slaughter' and 'Test and Segregation' are likely to be impractical in low-resource settings where infrastructure may be unreliable and space both between and on individual farms is limited. It also became clear that farmers called upon to implement biosecurity measures should be supplied with locally-specific information and instructions in order to effectively control and prevent the spread of disease. Additionally, this research supports the need for investment in animal health system strengthening in Ethiopia and other similar settings, in order to enable animal health workers, including veterinarians, to devote time to disease surveillance and farmer sensitisation. Similarly, investment in milk pasteurisation processes and public education on these processes should be prioritised in order to increase their acceptability and feasibility among both producers and consumers.

Introduction

This paper is based on an investigation into the views of Ethiopian dairy farmers, veterinarians and human health workers (HHWs) on potential strategies for controlling and preventing the spread of Bovine Tuberculosis (bTB) in the dairy sector and in Ethiopia more widely.

bTB is caused by the bacterium *Mycobacterium bovis* and is prevalent in a number of domestic and wild animal species. However, cattle are considered to be the main reservoir of the disease, which also has the potential to spread by zoonotic transmission, i.e. from animals to humans. The main routes of zoonotic transmission are through close contact, aerosol inhalation, and consumption of raw, unprocessed or under-pasteurised milk from an infected animal, but there is also a risk of transmission through consumption of improperly cooked or raw meat or organs from a diseased animal (Ashford et al., 2001; Etter 2006; Regassa, 2007). This study and the wider project of which it forms a part focus on the emerging commercial dairy sector operating in Ethiopia's urban and peri-urban areas. The cattle in this system are mainly 'exotic' *Bos taurus* breeds crossed with the local *Bos indicus* breeds (zebus) farmed intensively, meaning that they are primarily kept indoors with little or no contact with cattle in neighbouring farms. They are fed primarily with concentrate, without much access to outdoor grazing unlike the extensive systems in other areas of the

country where zebu cattle are kept in village herds grazing freely. The farms in these systems are predominantly small farms with five to ten cows and heifers kept in a small compound which is also the family home. Cattle are usually kept in a separate barn or in the house where the family lives a few yards away. These housing conditions lead to close contact between the animals (as well as with humans on farm) and often precipitate poor ventilation and spaces that are difficult to keep clean, increasing the risk of transmission and infection of contagious diseases such as bTB.

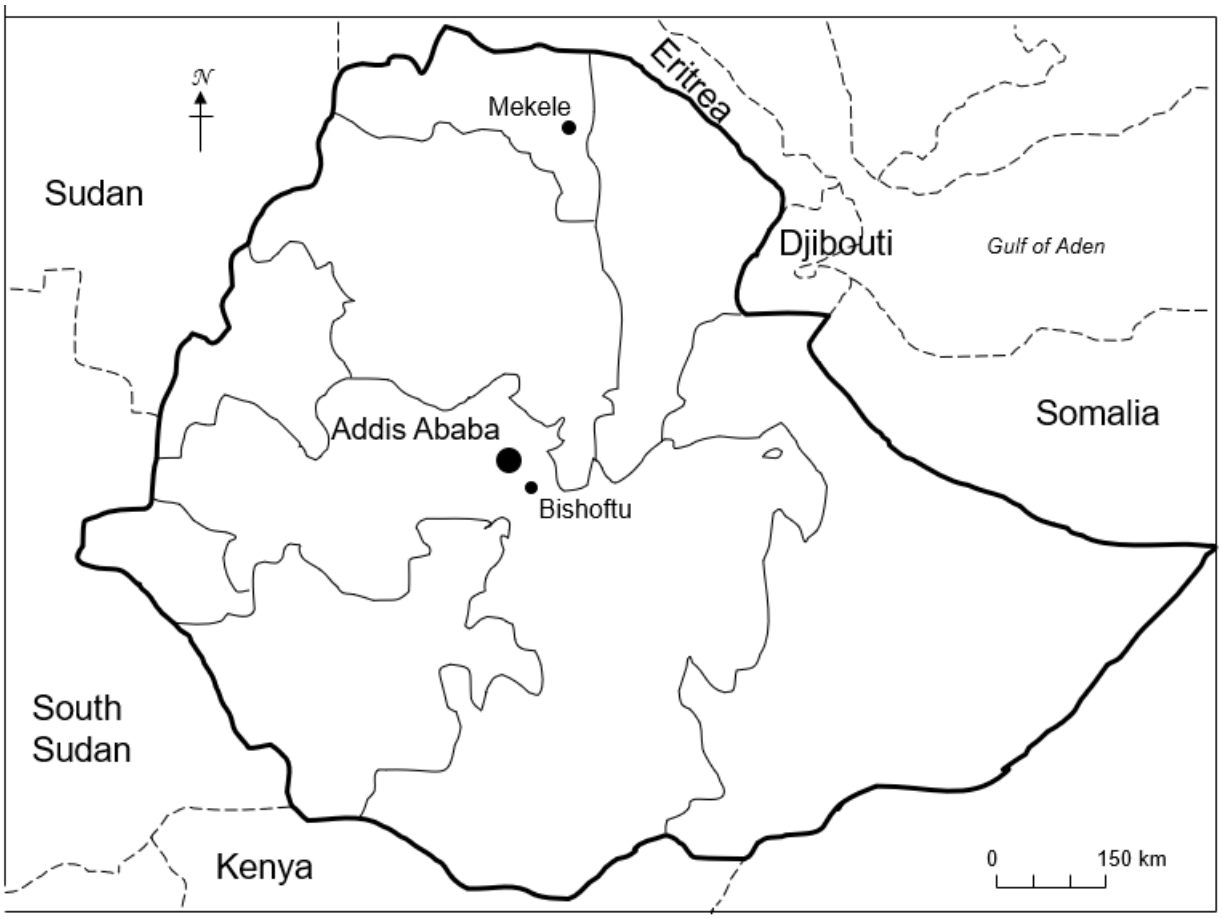
The animals employed in Ethiopia's urban and peri-urban dairy sector differ in several ways from the local zebu breeds of cattle, which have long been farmed extensively in the rural areas of the country. These local cattle, while well-suited to their climate, environment and intermittent work as draught animals, do not produce high milk yields but they are relatively resistant to infectious diseases. In order to improve the national herd and increase the production of dairy products with a view to creating an export market, the Ethiopian government has encouraged dairy farmers to invest in crossbreeding local animals with exotic breeds for several decades. These exotic breeds are European dairy cattle, such as Holstein-Friesian and Jersey breeds, which are more productive and primarily kept for milk production but they require higher quality feed, more water and appear to be more susceptible to a number of diseases, including bTB, as compared to zebu cattle. In fact, the prevalence of bTB in the intensive dairy sector is in many places of Ethiopia an order of magnitude higher as compared to the extensively reared farms with zebus (Asseged et al 2001; Firdessa, 2012; Ameni et al 2003; 2007; Tigre et al., 2012) when using the intradermal tuberculin test (OIE, 2009). However, despite such challenge, the Ethiopian government has primarily promoted the introduction of cross-bred animals to the national herd through an Artificial Insemination programme and has incorporated their plans for the development of the dairy sector into their Growth and Transformation Plans.

The fact that such intensive farming practices require no or smaller spaces for animals to graze, along with the expansion of urban areas across the country means that a considerable amount of this dairy farming using exotic and/or cross-bred cows is taking place in urban and peri-urban areas. Urban and peri-urban systems in themselves present challenges that differ from those evident in rural farming. While it may theoretically be easier to transport milk and other perishable products to an urban centre, where there is high consumer demand, space is at an absolute premium. Many urban dairy farmers find that their neighbours complain about the smell of their operations, and since the right to ownership of rural and urban land is exclusively vested in the State and in the peoples of Ethiopia, their status as temporary landholders mean that they are constantly vulnerable to eviction. For example, in a growing urban society that land can be earmarked for residential and/or industrial construction. The keeping of animals in close proximity to the dense human populations of urban settlements also increases the risk of zoonotic disease transmission, whether this be through the air, through increased consumption of animal products, and/or through the improper disposal of waste.

Focus Group Discussions (FGDs) were organised in two sites in Ethiopia: in Mekele, the regional state capital of Tigray (June 2018) and in the Oromia town of Bishoftu, which is situated 45km outside of the capital Addis Ababa (May 2019) 45 km. These two sites represent contrasting scenarios. Mekele was selected because it represents an emerging urban and peri-urban smallholder dairy system with low level of market development and milk pasteurisation, while Bishoftu represents an urban and peri-urban dairy belt where a number of large and medium farms are found with a well-developed milk pasteurisation and marketing system. The study formed part of the work carried out by the Ethiopia Control of Bovine Tuberculosis Strategies (ETHICOBOTS) project, an international, multidisciplinary research project, funded by the UK Research Councils' Zoonoses in Emerging Livestock Systems (ZELS) programme, and including researchers and institutions from Ethiopia, the UK and Switzerland. While the work on which

this article is based was carried out by anthropologists, veterinarians with an interest in social science and One Health approaches, and agricultural economists, the wider multidisciplinary project also includes veterinary epidemiologists, microbiologists and mathematical modellers.

Map 1: Map of Ethiopia with research sites



The aim of the ETHICOBOTS project is to gather evidence which the Ethiopian government and its agencies can use to develop strategies for the control and prevention of bTB particularly in the emerging intensive dairy system in the urban and peri-urban areas that is most affected by this disease. While the exotic and cross-bred cattle mentioned above currently make up less than 2% of the country's cattle population, the fact that the government has encouraged an increase in these numbers due to the perceived potential for higher milk yields (NPC, 2016) means that the intensive dairy sector is likely to increase in the coming years and decades. The increasing urbanisation of the population in Ethiopia, and in the sub-Saharan African region more generally, also leads to higher consumption and increased markets for meat and milk products, which, as is often the case, have been responded to in Ethiopia with programmes of agricultural intensification (FAO, 2004). These changing conditions could potentially bring with them an increased risk of zoonotic bTB transmission, making the development of effective, feasible and acceptable control and prevention strategies both important and urgent (Jones et al. 2013).

Study Objectives:

FGDs were employed in order to learn from farmers, veterinarians, local government agricultural officers, and community health workers about their perceptions of the challenges facing urban and peri-urban dairy farmers and more importantly to collect information on feasibility of researchers' proposed bTB control and prevention strategies from farmers' perspective. A further aim was to ask participants for their own ideas about how bTB and other key animal and human health problems faced by dairy farmers might be addressed. The participants in our FGDs were those who spend their daily lives interacting with cattle, monitoring their health and their behaviour and, ultimately, are the ones who make decisions about whether to sell, cull or segregate infected animals. It is therefore essential that any policy developed at the national level be acceptable to these key stakeholders and that the steps they must take to comply with that policy be feasible. The views of Human Health workers (HHWs), operating in the community are also crucial to developing effective strategies and policies for managing bTB, as they are empowered to be able to carry out both surveillance and educational outreach to the human population at risk of zoonotic infection. The vision of the One Health approach to zoonotic disease management is also one in which animal and human health workers work together, supplementing each other's experience and knowledge. It was therefore important to include community health workers in our FGDs.

Material and Methods:

Participants in the FGDs in both sites were recruited with the assistance of key informants, both from the local offices of urban agriculture, government veterinary clinics and from the Artificial Insemination service. They selected people who had been in the area and in the dairy business for some time with knowledge of the important issues in the sector, and those who were representative of their groups in terms of socioeconomic status. Four FGDs were held in Mekele and another four were held in Bishoftu. In each site, the four groups were organised as follows, with each containing six to eight participants:

1) Dairy farmers of both genders with fewer than 5 cows (50% split)
2) Dairy farmers of both genders with more than 5 cows (50% split)
3) Female dairy farmers with any number of cows
4) Veterinarians, Community HHWs, and Local Government Agricultural Officers

In each site, two of these farmer groups contained farmers of both genders, while one group was reserved for female farmers only. This proved useful in that, as well as ensuring that women who would have attended mixed-gender groups were not discouraged from speaking due to the presence of men, the women-only group in Mekele also included a group of three Orthodox Christian nuns (from a nearby convent with its own dairy farm) who would not have attended a mixed-gender FGD. There was no significant impact on gender representation in the study with any impact on the results, since mixed and single gender groups showed strong similarities.

A pre-prepared checklist was used to structure the FGDs, which were conducted in a mixture of Amharic (the official language of Ethiopia), which was spoken by the Ethiopian researchers and by the majority of FGD participants, particularly in the case of large farm owners, veterinarians, government agricultural officers and HHWs, and, in the case of Mekele, in Tigrinya, the regional language of Tigray. The lead Ethiopian researcher, an agricultural economist by training with considerable experience of facilitating FGDs has a good understanding of Tigrinya but does not speak it fluently. Therefore, a Tigrinya and Amharic speaker from the local Urban Agriculture Office, where the FGDs were held, was present to translate where necessary. Most of the discussion in both places was held in Amharic. Recordings were made of the FGDs and detailed notes taken. During the FGDs, Ethiopian researchers also translated into English for the benefit of their English-speaking colleagues, who were then able to ask follow-up questions

in response to participants' comments. We recognize that this system of two-way translation is far from ideal.

It is also noted that the location of the FGDs in the local government Office of Urban Agriculture may have affected some of the responses, especially regarding the effectiveness of the services provided by that office and its employees. The key informant who contacted farmers was also a provider of Artificial Insemination services, as well as being recognized locally as an expert in animal husbandry and regularly assisting with the birth of calves. However, he was not present during the FGDs.

One member of staff from the Office of Urban Agriculture was present during the farmer FGDs in Mekele, in order to translate between Tigrinya and Amharic when necessary. He stressed at the outset of all discussions, as well as when any questions about the services provided by the Office were asked, that he was not representing the office and that participants should feel free to be honest. The fact that participants were critical of the Office of Urban Agriculture in the presence of this figure suggests that they were not overly affected or intimidated, but this should still be recognized as a possible limitation of the study. All the participants in Bishoftu spoke Amharic fluently and were happy to do so.

Per diems were paid to all participants in order to cover the costs of their transport to the FGD location and refreshments were also provided.

Proposed Control and Prevention Strategies:

Following an open-ended question about what farmers would instinctively consider to be the best way of handling animals testing positive for bTB, participants were presented with the following proposed strategies for control and prevention of the disease which were drawn from the results of the ETHICOBOTs project and other bTB prevention and control programmes world-wide:

1) Vaccination
2) Strict regulation of animal movement with a certification system to show whether animals are clean or infected
3) Slaughter of infected animals following sale to a slaughterhouse
4) Segregation of infected animals from uninfected animals on the farm

More general practices for reducing the risk of zoonotic disease transmission in general and bTB in particular were also discussed. These included:

1) Implementation of on-farm biosecurity measures such as limiting the movement of people, use of disinfectant footbaths at the farm gate, wearing of protective clothing, cleaning of the farm using disinfectant etc.
2) Pasteurisation of milk
3) Cooking of meat

The following section is structured according to the different proposed control strategies and behaviours discussed in the FGDs. The cattle test referred to in Table 1 and throughout this paper is the intradermal tuberculin test which is the gold standard diagnostic test for bTB (OIE, 2009).

Table 1: Framework to guide discussion on bovine TB control strategies

Farm Size	**Prevalence**	**Short Term Strategy (within 2-3 years)**	**Long Term Strategy**

Small (1-15)	High	• Biosecurity measures • Preventing contact between herds through facilities (e.g. attendants, bulls, visitors etc.) • Separating calves from infected dams (bottle feeding/boiled milk feeding/surrogacy) • Use AI for breeding • Sell milk to pasteurisation plants or to farms with their own processing plant	• Regular testing of cattle for bTB • System of purchasing certified animals only • Regulation of animal movement • Vaccination
Small (1-15)	Low	• Test and Slaughter • Use AI for breeding • Separating calves from infected dams (bottle feeding/boiled milk feeding/surrogacy). • Sell milk to pasteurisation plants or to farms with their own processing plant	• Regular testing of cattle for bTB • System of purchasing certified animals only • Regulation of animal movement • Vaccination
Large (>15)	High	• Test and Segregate • Use AI for breeding • Separating calves from infected dams (bottle feeding/boiled milk feeding/surrogacy) • Sell milk to pasteurisation plants or to farms with their own processing plant	• Regular testing of cattle for bTB • System of purchasing certified animals only • Regulation of animal movement • Vaccination
Large (> 15)	Low	• Test and Segregate • Test and Slaughter • Use AI for breeding • Sale to farms with their own processing plant which may sell in urban areas • Separating calves from infected dams (bottle feeding/boiled milk feeding/surrogacy) • Sell milk to pasteurisation plants or to farms with their own processing plant	• Regular testing of cattle for bTB • System of purchasing certified animals only • Regulation of animal movement • Vaccination

Results and Discussion

On-Farm Biosecurity:

The farmers were presented with a series of pre-formulated biosecurity practices drawn from a review of good practice internationally, but they also came up with their own ideas and associated practices. Discussions in all groups began with questioning the farmers on their willingness and ability to implement on-farm biosecurity measures, including controlling the movement of animals and people between farms, the wearing of simple masks to protect against aerosol transmission of bTB, the use of footbaths, and cleaning of the farm with disinfectant. In all cases, farmers stated that while it would be possible for them to control the movement of large livestock animals, such as cows and donkeys from moving between farms, smaller animals, particularly cats and dogs cannot be so easily controlled. Although discussed, movement of cattle between farms was already deemed controllable and restricted for the reasons of bTB and other disease prevention, so no deeper discussion was held about its importance and feasibility. They also said that the movement of people on and off the farm is crucial to everyday operation and, even more so, to dealing with crises. If there is an animal health problem, people will come from other farms to assist, often before veterinarians are consulted. In general, farmers are open to the idea of using disinfectant footbaths at the entrance and exit of their farms, but they associate this practice more with poultry farming. They also pointed out that only cold water is available to them and that it is very difficult to access disinfectant chemicals. Both veterinarians and farmers pointed out that, while they would be prepared to use footbaths, the high rates of movement between farms would make their use very difficult to monitor. Similarly, the suggestion of wearing different outer clothes when on each farm was also considered to be impractical. Farmers are in the habit of washing cattle with soap, especially after they have given birth, but some find it very difficult to wash the interior of their farm buildings because the floors of the temporary structures, which are common in urban and peri-urban farms, easily become very muddy. Land leases in Mekele city are granted for a period of five years and farmers are forbidden from building permanent structures. One member of the female farmers' group in Mekele reported that she had attempted to build a structure with cement blocks in order to create more sanitary conditions for her animals, but that local authorities found out and dismantled the structure.

Veterinarians and Agricultural Officers from the local agricultural office believed that farmers lack awareness about the purpose and the effective implementation of biosecurity measures. They had observed that poultry farmers generally have better habits and a deeper understanding of biosecurity, largely because they have had prior trainings and experience dealing with highly contagious poultry diseases. A lot of the biosecurity problems in Mekele are also attributed by veterinarians and officials to 'improper site selection', with farms situated in the middle of urban areas, wither because they have always been so, or because the town has expanded and enveloped them.

In Bishoftu, we found that there is also no Amharic word that can be directly translated as biosecurity. It was suggested that the closest equivalent is 'tnikake', which is usually translated as 'caution'. When asked to explain what 'exercising caution' might mean to them in terms of preventing disease from entering onto their farms, members of the farmer groups mentioned that if there is a sick animal on a farm, no one from that farm should enter onto another compound. If it is necessary for a person to move between farms in this way, they should change their clothes in order to reduce the risk of carrying the infection with them. The farmers highlighted the need for veterinary professionals to take these same precautions, changing their outer clothing and footwear when moving from farm to farm. Farmers with more than 5 cattle were keen to point out that disease could easily be spread from farm to farm when veterinarians used the same needle to vaccinate or take samples from animals on different farms. They suggested that veterinarians should use a clean needle for each farm (notably they did not suggest a new needle for each individual animal, presumably because this would be considered unrealistic).

As in Mekele, farmers in all three groups in Bishoftu identified keeping the farm compound clean as a key element of on-farm biosecurity. Ideally, the animals should be washed every three days and the buildings cleaned with water with or without disinfectant. In the first group, one participant managed a herd of 46 cattle and had access to cleaning chemicals for the compound. However, others were not in the habit of using such chemicals. Again, the farmers stated that their ability to keep the farm clean in order to prevent disease emergence and transmission was compromised by the lack of water supply in the area. A lack of space both within and between farm compounds was also identified as a key barrier to preventing diseases from entering farms and from spreading within a herd.

Other sources of infection suggested by the farmers were parasites including flies, which are tackled using smoke, often from burning branches from the Ethiopian olive tree, which is believed to fumigate the farm. Additionally, contact between exotic breed dairy cattle and other animals, especially local zebu cattle, should be avoided, barns should be well-ventilated and both feed and water must be clean. Farmers identified the fact that zebu cattle can be carriers of diseases which they are themselves resistant to. They also pointed out that it can be very difficult to avoid contaminated feed, which is thought to harbor parasites, especially tics, particularly when it is purchased from rural areas. Feed merchants are unscrupulous, and many farmers agreed that they are known to dilute feed with sawdust. Such adulteration of animal feed appears to be common.

Pasteurising Milk:

Farmers in Mekele were generally aware of the human health risks surrounding the consumption of raw, unpasteurised milk. Indeed, members of the first group stated that they would be very happy to drink pasteurised milk, but that the lack of a processing plant in the area precluded this. Researchers had previously heard of there being a plant in Mekele and so questioned what had become of it. Farmers and agricultural experts from the local government office informed us that the plant had closed due to a lack of reliable milk supply. There is also a lack of interest in pasteurised milk products among the general population of Mekele. In both Mekele and Bishoftu, farmers stated that, while people may be aware that pasteurisation protects them from some milk-borne diseases, they are uninformed about the process itself, assuming that such an extended shelf-life must come from the addition of potentially harmful chemicals into the milk. Consequently, those who are aware of the risks associated with drinking raw milk would much rather boil milk themselves at home than source it from a processing plant. In the group of farmers with fewer cows, people also stated that they can tell when milk is unsafe. Indeed, if they 'know' that their animals are healthy, they are assured that their milk is safe to drink without boiling.

One of the members of the female farmers group was a manager at a farm owned by the international non-governmental organisation (INGO), SOS Children's Villages, which provides day care for the children of working parents in the city as well as running children's homes (SOS Children's Villages, 2019). She stated that children who use their services were not permitted to consume raw milk, or yoghurt made from raw milk. Other members of all groups said that, while their children were not generally allowed to drink raw milk, many of them ate fermented yoghurt, known locally as 'ergo', made with raw milk.

Veterinarians pointed out that there is in fact one small milk processing plant in the Mekele area, but that it has a relatively small capacity. They believe that people in the area are generally not accustomed to drinking pasteurised milk. While one of the benefits of pasteurisation is the extended shelf-life it provides (c. 3 days if not refrigerated), this is still not long enough to alleviate the issue of the Ethiopian Orthodox fasting periods, when animal products are not consumed, which makes business for processing plants very difficult to maintain in Ethiopia, particularly in the North (Ruben et al 2017). Veterinarians are also very concerned by the dearth of processing plants and of regulation and testing of milk safety and quality in the increasingly

popular urban milk shops where people consume milk and yoghurt, as well as buying it to take home. This lack of regulation persists despite the fact that Ethiopia has officially adopted 'American Milk Standards' following an Aflatoxin contamination incidence revealed in 2015 (ILRI, 2015).

The HHWs also regularly advise people that consuming raw milk puts one at risk of contracting bTB. They find that most people are generally happy to accept this as a fact and that most respond by boiling milk before drinking it. However, they also reported that people tend to believe that the fermentation process used to make yoghurt eliminates, or at least reduces, the risk of illness including bTB. Despite studies into the survival of *M. bovis* in fermented milk, there is currently limited evidence to support or refute this (e.g. Mariam, 2009; Michel et al., 2015).

Farmers in Bishoftu pointed out that, while they are not averse to selling their milk to pasteurisation plants in the area, there is currently no incentive to do so, with such plants tending to offer lower prices than milk collectors or direct consumers. While some of the participants were members of the local Ada Dairy Cooperative, providing milk to the Ada Processing Plant, the majority had relinquished their membership because of a lack of perceived benefits. In the past, processing plants offered training and advice to their suppliers and some of the farmers sourced their original animals from farms and plants managed by Dutch dairy companies operating in Bishoftu. While milk collectors and consumers will buy milk from the farm gate and will pay immediately in cash, there are additional costs to the seller when milk must be transported to a processing plant. The large processing plants in Bishoftu also pay every two weeks, which can be problematic if farmers have immediate cash needs. The demands of milk collectors also prevent dairy farms in Bishoftu from selling to pasteurisation/processing plants. Once the collectors have come to expect a certain amount from a supplier, they will complain if they are presented with less. Farmers stated that this stops them from selling to other buyers and means that they are often unable to keep much, if any, of their milk for their own consumption. As far as they are aware, the milk collectors supply to cafeterias and do not pasteurise milk, although they have the resources to refrigerate and transport the product. One possible policy intervention might then be to encourage milk collectors to process the milk that they buy and sell on, removing the decision from the producer.

One older man, who had been in the dairy business for over 30 years stated that a lack of public knowledge on the safety and quality issues surrounding milk posed a key barrier to the development of a pasteurisation habit in Ethiopia: "Our people don't know much about milk", he told us, "Everything white is not just milk. It has different qualities and can be dangerous". This view contrasted with the farmers in the first group in Bishoftu (those with fewer than 5 cows), who were all aware of the pasteurisation process, but were unsure of how the process worked and would never consider drinking it themselves. In their view, pasteurised milk has a reduced fat content, causing the taste of the milk to suffer, and they identify it as a product for city-dwellers who don't keep their own animals and don't realise that they are missing out on the superior taste and quality of fresh, unpasteurised milk. HHWs suggested that, for people to fully commit to boiling or pasteurising milk, there would have to be an effective demonstration of the effects of drinking raw milk. Currently, when the HHWs advise people against doing so, people tell them that they have been drinking raw milk for years without any problems and that there is no good reason for them to stop doing so.

Despite this view from HHWs, all three farmer groups in Bishoftu identified raw milk as a potential source of infection, with the farmers with more than 5 cows specifically mentioning bTB as a risk. They seek to mitigate this risk by boiling milk before drinking it. However, they are also aware of potential dangers associated with yoghurt which is made from raw, unboiled milk. Female farmers in the third FGD stated that this yoghurt can be a source of Typhus and Typhoid and that the containers can also be a source of infection, particularly if the yoghurt is left to ferment for more than three days, or if the containers are not well cleaned between batches.

Reducing/ Ceasing the consumption of raw meat:

In a quantitative survey of over 400 dairy farmers across Ethiopia, carried out as part of the ETHICOBOTS project, the consumption of raw meat (uncooked muscle meat and internal organs) was found to be lower in Mekele than in the other study sites, including the Oromia towns around Addis Ababa (which includes Bishoftu). This was reflected in the findings of the qualitative study that we report here. Nobody in the FGDs held in Mekele reported that they themselves ate raw meat, largely because they said it was impossible to determine its safety by looking at it. Members of the women's group pointed out that even if the animal is healthy at the point of slaughter, the meat can be contaminated during and/or after slaughter.

In the first group in Mekele, consisting of farmers with fewer than 5 cows, participants reported that some people in the area have found it a very easy decision to give up raw meat, because of their awareness of the risk of bTB transmission, but that others love the taste and continue to eat it. After one of the women told us that her father particularly loves raw beef and ate it regularly, we interrogated whether those who do and don't consume raw meat divide along age and/or gender lines. Participants did not see this as being the case and stated that they had observed no pattern in who does and does not consume raw meat.

HHWs regularly advise people of the risks of eating raw meat and suggest that they buy all meat from an abattoir or butchers' shop, rather than slaughtering themselves at home. While it is permitted to slaughter poultry and small ruminants at home/on one's own farm, municipal by-laws prohibit the home-slaughter of cattle. If HHWs, or other officials, become aware that 'backyard slaughter' is taking place, they will report it to a sub-city level regulatory body.

HHWs also found that those people who continue to eat raw meat tend to believe that the only real health risk they face is that of contracting tape worm. Because they are used to getting rid of tapeworms using traditional methods, which they see as tried and tested, this is a risk they are willing to take and does not cause them a great deal of concern.

Research participants in Bishoftu were generally more enthusiastic about eating raw meat and spoke of eating it more regularly than their counterparts in Mekele. This accords with the results of the mentioned survey by the ETHICOBOTS project, which found that rates of raw meat consumption in Mekele were considerably lower than in any of the other project sites, including the Oromia towns around Addis Ababa, which include Bishoftu. People in Bishoftu particularly enjoy eating raw meat during festive occasions, even though they associate its consumption with abdominal pain and discomfort. They attribute these symptoms to the presence of Typhus, Typhoid, amoeba and/or parasites, including tapeworm, within the meat, but did not identify any risk of bTB infection. The HHWs with whom we spoke in Bishoftu believed that the consumption of raw meat and raw milk was a much greater risk factor for bTB than contact with animals. They regularly see very young children with tapeworms and are aware that people continue to consume raw meat and milk despite the warnings that they give them.

One older man told us, however, that he heeds the warnings he has received against eating raw meat in order to prevent health problems. However, he went on to explain that he had also been warned of roasted meat as both raw and roasted meat would cause him to 'get old very fast'.

Test and Segregation:

Small-scale (<5 cows) farmers in Mekele were highly aware that, while they might be able to approximate some elements of a segregation programme following bTB testing, they would not be able to effectively segregate infected from uninfected animals, including ensuring no contact between animals, no shared utensils and no shared human attendants. On these small farms, particularly in urban and peri-urban areas,

there is not enough space to properly separate animals. There also tends only to be one person ministering to all the animals on a small farm and hiring more would not be financially viable. The farmers raised the ethical issue of keeping positive cows in their farm. Many farmers with small herds do not employ any farm workers but carry out all tasks on the farm alongside family members including their children. The group of farmers with more than 5 cattle and the group dedicated to female farmers in Mekele both contained participants who managed larger, well-planned farms with separate barns suitable for segregating animals which test positive for bTB. One of these farms is collectively owned by a cooperative of Tigray People's Liberation Front veterans, another by a group of nuns, and a third by the INGO, SOS Children's Villages. Even in these cases where separate barns and attendants may be available, research on the use of segregation to control bTB suggests that certain distances must be maintained for segregation to be effective at preventing the spread of infection (Ameni et al 2007). Discussants from these farms indicated that insufficient space is always a problem and complete separation of infected and non-infected animals with-in the same farm will be difficult in practice due to lack of space and other resources; test and segregate could rather be a short-term option to protect non-infected animals until any infected animal is culled.

Veterinarians in both sites commented that, even on large well-equipped farms, it would be difficult to ensure effective segregation without any sharing of equipment or facilities. They also questioned who would be responsible for policing the effective implementation of a national segregation strategy for the control of bTB and pointed out that any effective Test and Segregation strategy would also depend on a functioning pasteurisation system, as farmers would still need to sell milk from the infected animals in order to make their business viable.

One specific form of segregation sometimes suggested for the control of bTB is that the calves of bTB infected cows are separated from the mother (dam) as soon as possible after birth and so are prevented from drinking her potentially infectious milk. This particular issue was not discussed in Bishoftu, due to time constraints, but in Mekele farmers stated that they commonly separate cows and calves, although usually only a few days after birth. This was borne out on farm-visits where calves were often observed tied up in the farmyard, away from the adult cows which were kept within the barn. Farmers suggested that they could boil a cow's milk and feed it to her calf, but that encouraging a calf to drink from the teat of another cow would be very difficult. A key barrier to this for farmers in Mekele is the need for calves to take colostrum in the hours after birth, which is commonly suggested by veterinarians as a way of protecting calves from any infection in the first few days of life.

Similarly, farmers in Bishoftu highlighted the difficulties associated with segregating infected cattle from the rest of the herd. Members of the first group suggested that a combination of segregation of infected animals, vaccination of uninfected animals and preventing untested animals from entering the farm could be successful in controlling bTB. However, they added the caveat that segregation would only work if a small number of animals were found to be positive following testing. In such a case, farmers would segregate an infected animal as best they could, even if this meant tying the animal outside the barn, in a feed store or any other building. Because of lack of space and high construction costs, it would be very difficult for farmers to effectively segregate infected animals in a way that would prevent them from infecting healthy animals.

As in Mekele, those in Bishoftu also suggested that a viable solution would be for the government to commit to buy bTB positive animals at a higher price than that offered by slaughterhouses. This would enable infected animals to be separated from healthy herds and would prevent farmers from losing large amounts of money and even facing bankruptcy.

Test and Slaughter:

Overall, Test and Slaughter was a very unpopular strategy among dairy farmers in both sites. This is unsurprising given the financial losses incurred when slaughtering high-value cross-bred dairy cattle and the lack of compensation offered to farmers in such circumstances in Ethiopia.

Several participants in Mekele expressed the view that selling 'positive' animals to the slaughterhouse would never be an option for them because, even if the bTB status of the animal being sold is not disclosed to the purchaser, the amount the farmer would receive would be at most a third of the price of a healthy cow which could be used for dairy production. As Holstein-Friesian cross-bred animals in Mekele cost in the region of 30,000 Ethiopian Birr (ETB) (approx. $1,000), this is not a loss farmers can afford.

Despite being acutely aware of the ethical implications, most farmers stated that they would attempt to sell any of their animals that tested positive for bTB to other farms without disclosing their status. Most would not want to harm their neighbours in this way, especially as it would be easy for people to trace the infection to their farm, and so they would try to sell positive animals further afield. This finding should be taken very seriously by policymakers and others, including research institutions, carrying out Tuberculin testing, as there is a risk that doing so without proper follow-up could lead to infected animals being moved to other areas, spreading the disease as they go.

In the female farmers' group in Mekele, participants were more open to the idea that slaughtering positive animals might be a viable option. This was largely attributed to their view that once an animal was found to be infected, their milk should not be consumed in any form: raw or boiled, and especially not by children. Both the nuns and the manager of the SOS Children's Villages farm conceded that the larger size of their farms would give them a greater financial buffer, allowing them to slaughter a small number of animals without facing complete financial collapse.

Farmers in Bishoftu were also resistant to a Test and Slaughter strategy, citing similar reasons of financial loss and the vulnerability this would entail. When a cow is sold to a slaughterhouse, they can expect to collect between 10-15,000 ETB, compared to the price of a healthy cross-bred, which would be no less than 50,000 ETB in this region of Ethiopia. Some members of the first group relayed accounts of when they had taken a cow to the slaughterhouse and the slaughterhouse would not buy it. In the group of female farmers, there was disagreement around whether or not infected animals should be sold for slaughter, with some participants pointing out that, in addition to it being irresponsible to sell the milk of an infected animal, if anybody found out that a farm had had positive bTB test results, no one would buy from them and the price of all of their milk would fall as a result. Veterinarians in Bishoftu also questioned the efficacy of a Test and Slaughter strategy for controlling the spread of bTB, stating that people generally do not use or accept the abattoir service. Butchers tend to slaughter animals on their own premises, before taking the meat to a market to sell. This means that they bypass the meat inspection which takes place in abattoirs and risk contaminating the meat as it is processed and transported. The veterinarians were concerned that infected carcasses would be consumed by the public, possibly without being adequately cooked, if farmers were instructed to slaughter positive animals without further controls on how this was to be done. The vast majority of slaughter is performed in the informal system, and the municipal abattoir systems have very low bTB detection capacity (Biffa et al 2010).It was not only the economic impact which gave farmers pause when asked to consider test and slaughter. People are emotionally attached to their animals, with one woman describing them as 'like our children'. This is exacerbated by the fact that many dairy farmers in Ethiopia have built their herds up from the purchase of one cross-bred cow and the calves they produce from her through artificial insemination or the hire of a bull, meaning that they have raised most of their animals from birth. One of the nuns who participated in the female farmers' group stated that the Test and Slaughter strategy was unrealistic because, in her experience, people are unwilling to have their dogs killed

when they are infected, e.g. with rabies, and so she assumes that they will not be prepared to slaughter cattle which have more emotional and economic value to the whole family.

The emotional value of dairy cattle to urban and peri-urban farmers and their families is a topic that warrants further investigation, as while there has been much work carried out on the relationship between pastoralists and their cattle and between humans and companion animals in the Global North, there is a limited literature on the relationships which exist between small-scale livestock farmers in low and middle income countries and their animals, who tend to exist simultaneously as economic objects and intimate co-dwellers. Such work could inform policy on the management of animal health problems and zoonotic risk, including that associated with bTB, as well as providing a more accurate picture of the realities of emerging systems of urban and peri-urban agriculture.

Regulation of cattle trade and certification of individual animals:

In Mekele, the suggestion of a government certification scheme which would enable farmers to know the bTB status of an animal, at least at the last testing date, was initially received enthusiastically. However, it emerged through further discussion that both farmers and veterinarians felt that it would be very difficult for authorities to implement strict regulation of the trade of exotic and cross-bred dairy cattle, due to the informal nature of much of this trade. While local zebu breeds are frequently traded at formal market centres, the trading of exotic cross-breeds, according to farmers we spoke with in both Mekele and Bishoftu, is relatively rare outside of the sale of male calves for meat and, when it does occur, tends to take place through social networks, sometimes using the services of brokers (especially in Bishoftu).

The farmers recognised that they would be required to take collective responsibility for regulating such an informal market. An older woman from Mekele, who owned more than 5 cows, angrily expressed the view that all dairy farmers should be concerned with and take responsibility for controlling the spread of bTB through trade and movement. Indeed, she expanded this responsibility to the whole nation, which she felt shared a duty to protect its children. Other women in the same group stated that the government should make it public knowledge when a herd is found to contain animals that test positive for bTB. They related a story of a farmer in the area who had recently sold six positive animals to his neighbours, without disclosing their status. While it was difficult to establish evidence of this specific case, it was clearly a source of great anger and concern for the participating dairy farmers, who also stated that the government's failure to apply a certification system to the dairy industry was just one of many signs that they do not support the industry.

Veterinarians in Mekele expressed similar concerns about the reliance of any trade regulation scheme on personal collective responsibility on the part of farmers. They suggested that, for such a strategy to be effective in controlling and preventing the spread of bTB, it would have to follow a major education and awareness-raising effort, to ensure that people understood what is at stake if the disease were to spread across the country and beyond.

Dairy Farmers in Bishoftu also expressed support for the idea of a government certification scheme for dairy cattle. However, others stated that it would already be very difficult to sell a sick animal without the purchaser becoming aware. Although brokers will often exaggerate the productivity of an animal and may give false accounts of an animal's medical history, those buying animals will usually take a veterinarian with them to examine the animal. Such examination may not reveal bTB infection though and so certification would still be appreciated. In Bishoftu, however, dairy farmers were incredulous that the government would invest in such a certification scheme, stating that they are seeing no support from the government for the dairy industry, which, in turn, was leading to its decline.

Vaccination:

A conceptual discussion of vaccination was held with the participants in both study sites in order to understand their opinion on vaccination as a prevention option if it would become available someday in the future. The idea of controlling bTB using a vaccination programme was, overall, received positively. However, all participants were aware that vaccination campaigns are expensive and that the government would possibly not be able to afford to vaccinate all dairy cattle in the country. In Mekele, veterinarians suggested that, if an effective vaccine were to exist, vaccination should be combined with another of the control strategies, such as Test and Slaughter, with animals being tested, those found positive slaughtered and the remainder vaccinated, ensuring clean herds for the future. A successful vaccination programme would also require restrictions on cattle movement being implement in engaged farms.

The efficacy of a vaccination campaign would also depend heavily on the adequate resourcing of veterinary offices across Ethiopia: Farmers in Bishoftu described to us that they are very grateful for and appreciative of the service they receive from veterinarians, but that the efficacy of vaccination is limited by the fact that it is supply, rather than demand driven. When veterinarians have access to vaccinations, they will contact farmers, tell them the price and then administer the vaccines they have. The farmers in our FGDs were all willing and accustomed to paying for vaccines, but it is worth noting that a vaccination scheme paid for by farmers may not have universal coverage, as some farmers may not be able or willing to pay. The ability of veterinarians to provide comprehensive coverage in a vaccination campaign may also be compromised by their lack of access to transport. Veterinarians in both study sites reported that it can be difficult for them to travel to the more remote farms which come under their remit, often in peri-urban areas. In Mekele in particular, veterinarians stated that urban expansion has left them with responsibility for areas, which can be difficult for them to access as they are far from their offices in the town centre. Some government veterinarians and agricultural officers drive motorbikes, but others do not. While other animals, such as goats, sheep and local cattle can be brought to the government veterinary clinics for vaccination or other treatment, dairy farmers do not bring their cross-bred cattle to clinics as they are not as docile as the local cattle which can be driven along roads to veterinary clinics without too much difficulty, so they must pay for veterinarians to visit them on their farm, adding an additional cost to vaccination.

Alternative Suggestions:

In addition to asking participants to respond to the list of potential control and prevention strategies we had presented to them, it was also important to collect their own ideas about how bTB could best be managed, given that they are experts on their own contexts and the opportunities and limitations they provide. In the small farmer group in Mekele, it was suggested that the government, or another large, well-resourced organisation, could establish its own pasteurisation plant and purchase positive animals to supply milk. Because the milk from positive animals is rendered safe to drink by pasteurisation, the animal could continue to be productively used and so such a plant could offer a higher price to the seller of infected cattle than those offered by abattoirs and butchers. Both veterinarians and members of the group for farmers with more than five cows also suggested that the government should incentivise farmers not to sell positive animals to other farms without revealing their status by offering at least half of the initial price of the animal as compensation, *i.e.* c. 15,000 ETB.

A fairly obvious problem with the first suggestion is that, returning to the previous discussion about people's suspicions surrounding the pasteurisation process, it seems unlikely that there would be many enthusiastic consumers of pasteurised milk from bTB positive cows, even if they were assured of its safety.

In both Mekele and Bishoftu, FGD participants also suggested the introduction of an insurance scheme for livestock farmers in Ethiopia. They noted that there is currently a government insurance scheme available

to arable farmers, but that no such thing exists for livestock. The dairy farmers expressed their worry about the availability of tuberculin test service which is one of the determining factors to clean their farms from bTB. If the service is available as clinical service given by the government clinics, it could be a good opportunity for them to test the health status before purchasing and selling of dairy cows.

Table 2: Summary of findings on control strategies for Bovine Tuberculosis:

Biosecurity	− Uncontrolled movement of domestic and wild-live animals on farms − Lack of awareness on germ transmission − Cost for adopting biosecurity measures can be high + Once infection and risk factors are understood, farmers show willingness to adopt prevention
Pasteurization	− Misconceptions on the process and content of pasteurised milk + Government should adopt pasteurisation as an option for zoonotic prevention
Test and Segregation	− Depends on availability of sufficient segregation space − Effective monitoring of separation and strict biosecurity measures
Test and Slaughter	− Without compensation, large financial losses to farmers + Most efficient way to clean farm from bTB + Most viable among large farms with sufficient financial capital
The farmers' alternative	+ Government should establish farms that takes on and segregates infected cattle + Establishment of insurance schemes for dairy farming

Conclusions

Several conclusions, particularly relevant to policymakers and others addressing bTB disease control in Ethiopia and other low-resource settings may be drawn from this qualitative study. While FGDs were carried out in only two sites at this stage, the decision to speak with farmers with different sized farms, to hold groups solely consisting of female farmers and to consult veterinarians and HHWs provides an overview of conditions and opinions across the two sites. Interestingly, there were no significant variations in responses between single gender and mixed gender groups, suggesting that all farmers experience similar constraints and challenges with regard to disease control, but as noted above larger farms (> 5 animals) tended to have more resources and a greater ability to mitigate risk. Analysis of the findings raises a number of issues that warrant further investigation and consideration when designing and implementing control strategies for bTB:

Firstly, local context matters, both in terms of the knowledge and attitudes of farmers and in terms of the resources and infrastructure available to them. Both factors have considerable impact on the acceptability and feasibility of any policy intervention, as, when policies are not differentiated in order to provide alternative implementations for those without access to key resources, they become irrelevant and ineffective in those low-resource areas or sectors. In Mekele in particular, the lack of an adequate water supply to many farms, and a lack of information about and access to effective disinfectant chemicals render instructions to regularly clean the farm premises with hot water and disinfectant and to set up footbaths at the entrance and exit irrelevant to urban and peri-urban dairy farmers. Policies and instructions should be adapted to meet the realities of available infrastructure, or, preferably, the infrastructure and information needed to ensure effective implementation should be provided. We recognise that this is difficult in a context of limited resources and competing priorities, but such investment would lead to improvements for both human and animal health well beyond the issue of bTB.

Secondly, perceptions of, and consequently responses to, risk vary between different stakeholders. While bTB may be a key concern for national and international institutions concerned with national and international public health and the development of a viable export industry, there are risks, both to health and to livelihoods, which are of greater concern to dairy farmers in Ethiopia. The likely financial costs of many of the proposed control strategies, including Test and Slaughter and Test and Segregation pose a more immediate threat to farmers than long-term risks of a disease whose effects, at least in the short term, are difficult to see. For farmers to fully 'buy into' bTB control and prevention strategies, the financial risks of doing so should be lessened, whether this be through insurance and compensation schemes, or through support for the milk pasteurisation industry in Ethiopia. If a commitment to selling milk only to pasteurisation plants will result in considerable financial loss because of the low prices offered as compared to direct consumers and milk sellers, farmers are unlikely to make such a commitment. At a more existential level, if slaughtering positive animals rather than selling them to another, far away, farm without disclosing their status, will lead to complete loss of livelihood with all that that entails, it is hardly surprising that they may choose the latter option, despite the wider harm to the industry and other farmers.

Another key factor likely to determine the success of any policy in controlling and preventing bTB in the Ethiopian dairy sector is trust and integrity. Surveillance and control programmes rely on trust, both between individual members of the dairy farming community and between those farmers and the veterinarians, health workers and other representatives of regional and national government with whom they come into contact whether in person and/or through the media. This applies to the issues of pasteurisation, which is treated with suspicion by many farmers and other milk consumers, as well as to the effects of the current tendency for farmers to sell infected animals to other farms without disclosing their status. While bonds between dairy farmers in their locality, also exhibited through mutual assistance during times of crisis, generally seem to stop farmers from selling infected cows within their own area (although the veracity of this claim is difficult to establish given the presence of those other farmers in the room when it was made), that same sense of solidarity does not extend those farmers who are outside the local area. Due in part to the lack of compensation for the loss of an animal sent for slaughter, passing the problem of an infected animal onto a stranger, at a distance where any consequences cannot be seen is currently the most viable solution to the problem of bTB infection for many farmers.

When devising control and prevention strategies for bTB and other potentially zoonotic diseases in the Ethiopian dairy sector, policymakers should take these findings into account and address them with understanding of social and infrastructural realities in addition to scientific and technical rigor.

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