From cow to consumer: using value chain approaches to evaluate infectious disease risk along dairy value chains serving urban consumers in Moshi Municipality, northern Tanzania

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Abstract

The global population is rapidly urbanising, with East Africa experiencing some of the fastest rates of urban growth. Urbanisation drives changes in diet, including increased consumption of animal source products (ASPs), and livestock value chains are becoming increasingly long and complex to meet these demands. This may place urban consumers at increased risk of food-borne infectious diseases. Evaluation of food-borne disease (FBD) risk to urban consumers in developing countries has been hampered by a lack of data on the composition of urban diets, and a lack of methodologies to systematically assess risk along food value chains which are typically informal, unregistered, and unregulated. This research used a value chain risk assessment approach (VCRA) to evaluate food-borne infectious disease risks along dairy value chains supplying Moshi Municipality, the regional capital of Kilimanjaro, Northern Tanzania. Our findings demonstrated that by far the most frequently consumed products were unpackaged milk and *mtindi* (fermented milk). While there was some role for urban livestock keepers in supplying these products to their communities directly, most of the milk and *mtindi* sold within Moshi originated with milk produced by smallholder farmers in rural areas surrounding the towns. Both the milk and *mtindi* value chains involved similar value chain nodes and actors, with a large degree of overlap between the formal and informal sectors and little to no formal education or training on milk handling and hygiene for chain participants. VCRA identified the bulking, wholesale and retail stages of the value chain as potential hotspots for introducing infectious disease risk. Consumers were well informed about many of the FBD risks posed by milk, and took active steps to mitigate these risks by boiling before consumption; however they perceived *mtindi* as posing a lower risk and were unable to mitigate risks with any preparatory step as *mtindi* is consumed as purchased. The highest risk to consumers was estimated to be posed by *mtindi* rather than milk, particularly *mtindi* made from leftover unsold milk, as this milk had a high risk of contamination. More studies are needed to investigate the infectious hazards present in both *mtindi* and other fermented milk products which are consumed widely across the region. The practice of valorising leftover ASPs as alternative products for human consumption may represent a particular source of FBD risk to urban consumers in developing countries.

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Author's declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is the result of my own work and has not been submitted for any other degree or professional qualification at the University of Glasgow or any other institution.

Abbreviations

AFM1	Aflatoxin M1
AMR	Antimicrobial residues
ASP	Animal Source Products
BSE	Bovine Spongiform Encephalopathy
C&D	Cleansing and disinfection
CI	Confidence Intervals
DALDO	District Agriculture And Livestock Development Officer
DALY	Disability Adjusted Life Year
DPU	Dairy Processing Unit
FANTA	Food and Nutrition Technology Assistance
GIS	Geographic Information Systems
GPS	Global Positioning System
HACCP	Hazard Analysis and Critical Control Points
HHS	Household Hunger Scale
HPAI	Highly Pathogenic Avian Influenza
KCMC	Kilimanjaro Christian Medical Centre
KII	Key Informant Interview
LAB	Lactic acid bacteria
LEO	Livestock Extension Officer
LFO	Livestock Field Officer
LMIC	Low and middle income countries
MCC	Milk Collection Centre
MVLS	College of Medical, Veterinary And Life Sciences, University Of Glasgow
NGO	Non-Governmental Organisation
OECD	Organization for Economic Co-operation and Development
PII	Personally Identifiable Information
TBC	Total Bacterial Count
TBS	Tanzania Bureau Of Standards
TCC	Total Coliform Count
TDB	Tanzania Dairy Board
TFDA	Tanzania Food and Drugs Authority
TLMI	Tanzania Livestock Modernization Initiative
TPC	Total Plate Count
TSh	Tanzanian Shilling
UHT	Ultra-High Temperature processing
WASH	Water, sanitation and hygiene
WEO	Ward Executive Officer

Glossary of Kiswahili and other terms

amasi	fermented milk (Zimbabwe)
chai	hot drink made by boiling milk with tea and spices
cowboy	young man employed by a household specifically to manage cattle husbandry and milking
dala dala	minibus used for public transport
Ergo	Ethiopian fermented milk product
horu	Kichagga term meaning bodily power, strength or force
hotel/hoteli	cafeteria, canteen or restaurant – sometimes but not always attached to a hotel
kitalolo	a Chagga dish made of *mtindi* mixed with bananas and either green vegetables or maize flour
loshoro	an Arusha Maasai dish made of *mtindi* mixed with ground maize flour porridge
Mama Lishe	female street vendor cooking and selling simple meals and refreshments
maziwa mala	Kenyan Kiswahili term for fermented milk, same product as *mtindi*
mlaso	*mtindi* mixed with blood
mtindi	fermented milk
mzungu	white western person
shamba	field; small agricultural area used for growing crops
ugali	thick dough made of maize flour
uji	maize flour porridge
wa kisasa	modern (referring to modernised, more intensive methods of animal husbandry)

Introduction

1.1 Summary

The global population is becoming increasingly urban, with East Africa experiencing one of the fastest rates of urban growth. Urbanisation drives changes in the way that people consume food owing to several interacting factors including changes in food affordability, availability, convenience and desirability. A common feature of the urban diet is an increased demand for animal source products (ASPs) compared to rural counterparts. This includes dairy products, which are an important nutritional staple in many countries but can harbour several pathogens harmful to human health. ASP value chains in developing countries are responding to the increased demand from urban centres by becoming longer and more complex in order to ensure that supply meets demand. This increased complexity can facilitate the introduction and propagation of pathogens hazardous to human health along ASP value chains, putting the urban consumer at increased risk of food borne disease (FBD). Despite this, the impact of urbanisation on FBD in developing countries is not well characterised, firstly due to a lack of data on urban diet composition and consumption habits, and secondly due to a lack of established methodologies to assess FBD along food value chains in these settings. This research seeks to contribute to addressing this gap by using a value chain risk assessment approach to explore the food-borne infectious disease risks to urban consumers posed by dairy products in Moshi Municipality, the increasingly urbanising capital of Kilimanjaro region, northern Tanzania.

1.2 Urbanisation and food choice

The global population has become rapidly more urbanised during the last century, with over half of the world’s population now living in cities for the first time in history (United Nations Populations Fund, 2007; United Nations Dept of Economic and Social Affairs, 2012). Whilst East Africa is currently one of the least urbanised areas of the world, it has the fastest rate of urban growth, with the number of urban dwellers predicted to double from 50.6 million in 2007 to 106.7 million by 2017 (United Nations Human Settlements Programme, 2008). As in many African countries, most urban growth in East Africa is occurring in secondary and tertiary settlements, in and around towns with less than 500,000 inhabitants (United Nations Human Settlements Programme, 2008). In regions other than Africa, urbanisation has been driven by the socio-economic benefits of industrialisation; however, urbanisation in Africa has been primarily poverty-driven and is mainly due to the "push" effect of rural poverty rather than the economic "pull" of urban centres (Von Troil, 1992; United Nations Human Settlements Programme, 2008; Bryceson *et al.*, 2009; Awumbila, 2014). Urban economies and infrastructure have not kept pace with the rate of expansion, with the result that informal and unplanned settlements have developed in and around African cities continent-wide, with inadequate access to housing or basic services such as water, sanitation, electricity and roads (United Nations Human Settlements Programme, 2008).

Urbanisation changes the way that people consume food; it not only increases food demand through increases in population, but it also drives changes in demand owing to the special characteristics of the urban food environment in which consumers find themselves situated (Satterthwaite *et al.*, 2010; Global Panel on Agriculture and Food Systems for Nutrition, 2016b; Seto and Ramankutty, 2016). Food environments are multi-faceted and serve both to drive and constrain food choices. Herforth and Ahmed (2015) conceptualise food environments as encompassing four main features: availability, affordability, convenience, and desirability.

Urbanisation affects food *availability* in terms of the types of foods that can be found in the town, and where and how easily those foods can be acquired. Different types of food become available in urban settings through new value chains arising, or existing ones adapting, to serve the growing demands of the urban population. For example, previously seasonal foods might be found year-round; commercially processed foods become more widely available; or the ethnic mix of a town or city might be reflected in the variety of foods sold within it (Global Panel on Agriculture and Food Systems for Nutrition, 2016b). In addition, consumers have a greater selection of outlets from which foods can be acquired, for example supermarkets, shops, street hawkers, urban livestock keepers, restaurants and cafés (Rae and Nayga, 2010). This increasing diversity in foodstuffs combined with the increased diversity in food outlets means that urban consumers can potentially access a more diverse range of dietary components.

The *affordability* of various foods will obviously modulate consumer food choice, particularly in low and middle income countries (LMICs) where the poor spend as much as 50-80% of their income on food (Brinkman *et al.*, 2010). A recent review found that in low income countries, a 10% increase in the price of dairy products would reduce their consumption by an average of 7.8% (Cornelsen *et al.*, 2014). However, although important, affordability cannot be considered in isolation as a driving factor for food choice. For example, through analyses of shifts in the global diet over three decades, Drewnowski and Popkin (1997) demonstrated that rapid urbanisation impacts on the structure of the diet regardless of income. Using regression analyses to investigate associations between Gross National Product per capita, the proportion of urban-dwellers compared to rural, and macronutrient consumption per capita in 98 countries from 1962-1990, the authors found that urbanization, although associated with greater incomes and economic growth, had independent effects on diet structure such as higher consumption of fats and sweetener. Herforth and Ahmed (2015) argue that the effect of income on dietary consumption is always modified by the wider food environment, as this environment serves to signal (and constrain) consumers to buy certain foods. The food environment affects diets by circumscribing what foods are available to consumers (and thus what they are able to spend their income on), as well as how likely consumers are to spend that income on those foods (based on the affordability, convenience, and desirability of the available foods).

Urban lifestyles also drive a need for increased *convenience* in food choices. As people spend more time working outside the home, so they have less time for food acquisition and preparation (Herforth and Ahmed, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016b; Seto and Ramankutty, 2016). This is particularly the case for women in paid employment, as women are often responsible for preparing household meals as well as participating in paid labour. The time required to obtain and prepare food can present a challenging burden, driving the demand for time-saving foods (for example food items that are pre-packaged or processed) as well as street food and meals purchased outside the home (Rae and Nayga, 2010; Herforth and Ahmed, 2015; Seto and Ramankutty, 2016).

Finally, urbanisation shapes food *desirability*. This refers not only to the sensory properties of food (such as taste, aroma or texture), but also to external factors that may influence food norms (Herforth and Ahmed, 2015; Seto and Ramankutty, 2016). The ubiquity of advertising, food marketing and product placement in towns and cities is an obvious influencer of consumer preferences (Global Panel on Agriculture and Food Systems for Nutrition, 2016b). Consumption of some foods may become aspirational, signifying social success or belonging to a particular group (Berger and Rand, 2008; Tarrant and Butler, 2011). Consumer education or health campaigns can additionally influence food choice (Auld *et al.*, 2000; Satia-Abouta *et al.*, 2002; Herforth and Ahmed, 2015). Moreover, the mixing of people from different ethnicities, cultures and backgrounds that occurs in the urban space can modify food norms. Food intake and food choice has been demonstrated to be highly modulated by social context (Robinson, Blissett and Higgs, 2013), and greater exposure to different kinds of foods, as well as different cuisines and styles of eating, can shape the diet of the urban dweller (Seto and Ramankutty, 2016). Over time, migrants have been shown to adapt to and adopt the dietary norms and patterns of their new environment in a process called dietary acculturation (Satia-Abouta, 2003). Lastly, urban infrastructure and architecture can themselves have an effect on food desirability. For example, urban dwellers may have access to electricity and refrigeration, which can affect their food choices (Rae and Nayga, 2010; Seto and Ramankutty, 2016). Urban living spaces may be small, affecting the amount and types of foods that can be stored or prepared at home.

Urban populations in Sub-Saharan Africa are undergoing a “nutrition transition” (Neumann, CG *et al.*, 2010; Steyn and Mchiza, 2014). First conceptualised by Popkin (1994) after studying dietary changes over time in developed countries, the nutrition transition describes generalised shifts in diet at a community level that occur as a society becomes more industrialised. One key feature of the nutrition transition is that urbanisation drives increased consumption of animal source products (ASPs -i.e. meat, milk and eggs). This leads to a paradox: as urbanisation progresses, demand for ASPs increases at the same time as the growing town converts nearby agricultural areas into non-food producing areas, creating challenges for supply to meet demand (United Nations Human Settlements Programme, 2008). Livestock systems are undergoing structural transformation in response to urbanisation, with management practices, levels of intensification, size of operations, spatial location and livestock species continuing to change (Pingali and McCullough, 2010; Schneider, 2010). Increasingly, ASP value chains are becoming lengthier and more complex (de Haan, Gerber and Opio, 2010; Gerber *et al.*, 2010). In the journey “from stable to table”, there may be multiple points of transaction and trade, numerous steps of processing and packaging, long distances to be covered, and many different groups of actors working all along the chain to make all of these stages happen (Rich *et al.*, 2011).

1.3 Food borne disease

Although zoonotic disease risk is often considered to be higher in poor, rural communities who are in close contact with livestock (Grace *et al.*, 2012), there are three factors that suggest that the rapid urbanisation in developing countries might put urban consumers at higher risk of food-borne disease (FBD) from ASPs compared to their rural counterparts. Firstly, the long, complex ASP value chains serving towns and cities provide multiple opportunities for pathogen introduction and transmission during the route from stable to table, potentially facilitating the spread of pathogens across wide geographical areas and to multiple consumers (Rich *et al.*, 2011). Secondly, the rapid nature of urbanisation frequently means that urban expansion occurs too fast for adequate infrastructure and effective regulatory governance to keep up, therefore failing to respond adequately to risk (United Nations Human Settlements Programme, 2008; Bonfoh *et al.*, 2010; Opio and Steinfeld, 2010; Grace, 2015). Thirdly, urban dwellers consume increased quantities of ASPs (Popkin, 1994; Neumann, CG *et al.*, 2010; Steyn and Mchiza, 2014), and are thus more frequently exposed to foodborne pathogens than rural dwellers. However, until recently, food safety and FBD in developing countries have been largely overlooked as areas of study. Research and policy priorities have tended to focus on food and nutrition security over food safety; on how the urban nutrition transition impacts on the burden of non-communicable disease (e.g. obesity and overweight) rather than FBD; and on improvements to water, sanitation and hygiene (WASH) rather than food safety to reduce the burden of diarrhoeal disease (Opio and Steinfeld, 2010; Satia, 2010; Chan, 2014; Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016b).

In 2015 the World Health Organization (WHO) published global estimates of the burden of 32 diseases caused by 31 food-borne hazards (WHO 2015). This report estimated that together, the 31 global hazards caused 600 million foodborne illnesses and 420,000 deaths in 2010, with the most frequent causes of FBD being diarrhoeal diseases. Children under 5 years of age experienced 40% of the FBD burden despite being only 9% of the global population. The research revealed considerable regional differences in the burden of FBD, with LMICs being the worst affected, and the highest burden per 100,000 population observed in East Africa. The report highlighted that despite the considerable burden of FBD worldwide, there were very few studies investigating FBD epidemiology and prevention, and called on countries and international agencies to dedicate more attention to food safety. The Global Panel on Agriculture and Food Systems and Nutrition (2016a; 2016b) has since identified improving food safety in LMICs as a priority, highlighting urbanization as an important potential driver of increased FBD.

There are currently two key barriers to investigating the risk that FBD poses to urban consumers in developing countries. Firstly: there is a lack of data on the urban diet. Despite widespread recognition that urbanisation drives changes in food demands for the reasons described earlier, data on current urban food consumption habits in developing countries are fragmented and incomplete. Data tend to be collected at the macro-level, for example quantities produced, purchased or sold, with diet structures inferred from this information on the basis of many assumptions (Popkin, 1998; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). Empirical dietary data at the household or individual level are sparse. The Global Panel on Agriculture and Food Systems and Nutrition (2016b) has thus identified the improved collection of dietary data as an urgent research priority worldwide, noting that few national governments collect the data necessary to inform decision makers about what people actually eat. This impedes the formulation of evidence-based research and policy surrounding changing food systems and urban health.

Secondly, there is a lack of established methodologies to assess FBD along food value chains in developing countries. In developed countries, FBD risks are assessed using formalised systems of risk analysis which have become keystones of international trade (Grace *et al.*, 2008). Risk analysis enables information on the hazards in food to be linked directly to information on the risk to human health, and provides a transparent and evidence-based approach to improving food safety decision-making (Grace *et al.*, 2008; Opio and Steinfeld, 2010). Through the risk analysis process, risk is systematically considered along the entire value chain from "stable to table" through a variety of codified systems, such as the Codex Alimentarius (CA), Good Agricultural Practice principles (GAP), and Hazard Analysis and Critical Control Points system (HACCP) (Opio and Steinfeld, 2010). However, in an article calling for new approaches to ensure safer food in vulnerable African communities, Grace *et al.* (2008) note that although systematic risk assessment is current best practice in developed countries for identifying critical control points where risk arises in food systems and where mitigation strategies might be put in place, its use in developing countries has been limited. The authors argue that in particular, risk assessment has not been applied to domestic markets where most poor people buy and sell food, but where hygiene and food safety levels are lowest and consumer vulnerability to FBD highest. Part of the reason for this may be the marked contrast between the organised, vertically integrated and well-documented food systems of developed countries compared to the largely unregistered, unregulated and constantly shifting food systems common to developing countries, where informal value chains are often the main link between rural smallholder farmers and the growing demand for ASPs in urban centres (Grace *et al.*, 2008; Costales, Pica-Ciamarra and Otte, 2010). This viewpoint is echoed by Omore *et al.* (2001), who go further to argue that current international food standards setting processes are not adapted to developing country contexts with the result that they are not fit for purpose in those countries. The authors suggest that food policy makers often over-rely on international standards that mainly recognise formal markets, usually due to a lack of locally derived evidence. The failure to recognise the dominance of informal markets leads to ineffective and poor regulation of food standards (Omore, Arimi and Kang'ethe, 2002).

Omore *et al.* (2002) call for a comprehensive documentation and characterisation of the hazards and risks associated with dairy and meat marketing in African countries and how these might lead to adverse health effects. They argue that this will serve to inform decisions on the most effective risk management strategies to mitigate against FBD, as well as facilitating context-appropriate standards setting. This call is supported by Kurwijila, the chair of the Tanzania Dairy Board, and colleagues (2011) in a situational analysis report examining the safety of animal source foods in Tanzania. The report states that the informal sector commands the largest share of the food market, but there is a country-wide lack of data on the volumes of meat and milk traded, proportions inspected, and incidence of food safety failures in this informal market. There are thus few food surveillance data in Tanzania on which to base risk assessments of foodborne hazards and/or to justify subsequent risk mitigation strategies. The report notes that regulatory authorities such as the Tanzanian Food and Drugs Authority (TFDA) do not use formal risk assessment methods such as those outlined by the international food standards of Codex Alimentarius (CA) or by the World Organization for Animal Health (OIE), a limitation also noted by the authors of a report into nutrition and food safety in dairy value chains in Tanzania (Haesler *et al.*, 2014). Instead, the authorities assess risks without a documented framework, with the result that only food safety threats of an epidemic nature receive much attention either from the media or from government interventions. Given this background, the authors of the report advocate for the development of simplified risk assessment methods that could be applied in the Tanzanian context in order to identify areas where risks may be occurring and contribute to a reduction of food safety hazards.

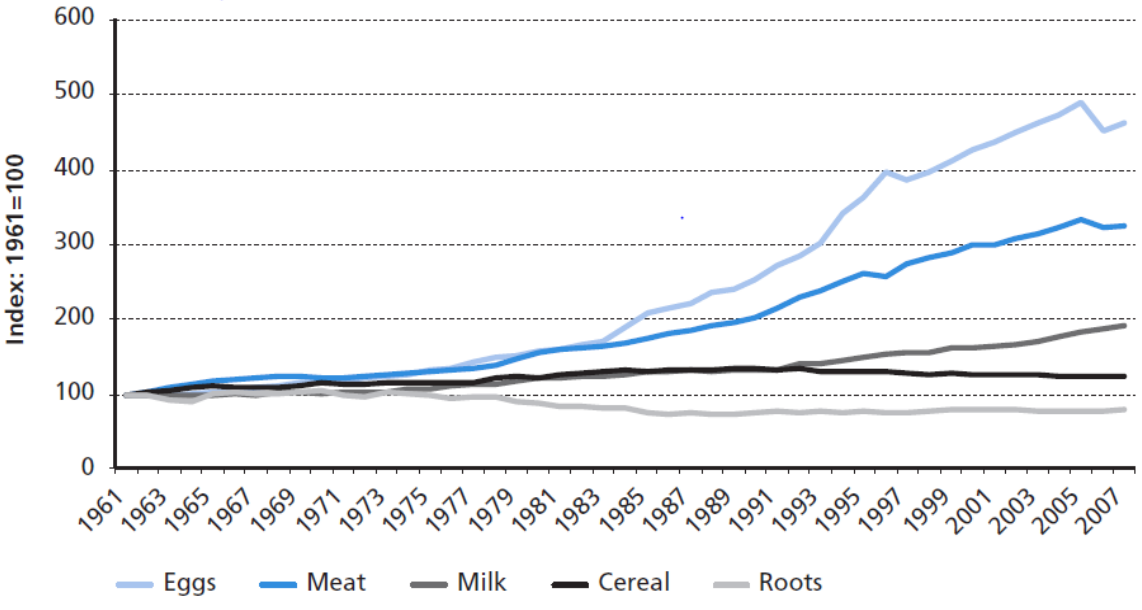
1.4 Dairy consumption and food borne disease

As with all ASPs, there has been a rapid increase in dairy consumption in the developing world over recent decades, with milk consumption in developing countries almost doubling between 1961 and 2007 (FigureFigure 1-). While the rate of increase in meat consumption in developing countries is projected to slow down over the coming decades, no such slowdown in dairy consumption is foreseen (Rae and Nayga, 2010). Total dairy consumption is predicted to increase by 50% by 2030 and then by another 16% by 2050 (Rae and Nayga, 2010). According to the Organization for Economic Co-operation and

Development (OECD) and the Food and Agriculture Organization (FAO), the dairy sector will remain one of the fastest growing agricultural subsectors over the coming decade in terms of production, with most of the expansion projected to occur in developing countries (FAO 2013). While all developing country regions are projected to see sustained growth in dairy production, the highest rates of growth are predicted in Sub-Saharan Africa and India (FAO 2013).

While dairy products represent an important dietary staple in many regions of the world and are a rich nutritional source of energy, readily digestible protein, and bio-available micronutrients such as calcium, magnesium, phosphorus, selenium, zinc, vitamins B1, B2 and B12, they can nonetheless pose a wide range of hazards to human health (Latham, 1997). The very fact that milk and dairy products are generally rich in nutrients means that they provide an ideal growth medium for many microorganisms (FAO 2013). Claeys *et al.* (2013) recently compiled a review of the multiple and diverse sources of the pathogens hazardous to human health that can be found in raw cow milk. Table 1-1 lists the pathogens that can be found in raw cow milk, together with an overview of the diseases that they cause and the source of contamination of the milk (pathogens can either be introduced from the cow at point of milking, from contamination during the milking process, or from contamination further along the value chain). As is evident from the table, a variety of disease syndromes can be caused by consumption of milk, due to

FigureFigure 1-1 Per capita consumption of major food commodities in developing countries, 1961-2007 (FAO 2013)



bacterial infections or due to toxins the bacteria produce. Incubation periods can vary from a few hours/days for some of the gastrointestinal pathogens (or even less for intoxications) to weeks or even months for febrile conditions.

Heat treatment adequate to ensure pasteurisation eliminates all vegetative bacteria in milk[1], including the organisms listed in Table 1-1. There are different heat treatment options to ensure pasteurisation; for example for “high temperature short time” (HTST) pasteurisation involves heating milk at 71-74^{0}C for 15-40 seconds; while “low temperature long time” (LTLT) pasteurisation involves heating milk at 63^{0}C for 30 minutes (WHO & FAO 2011). However, pasteurisation does not destroy already formed, heat-resistant enterotoxins of *Staphylococcus aureus* and *Clostridium botulinum B* toxins or the emetic toxins of *Bacillus cereus*. In addition, pasteurisation may induce the germination of heat-resistant *C. botulinum* or *B. cereus* spores which can subsequently grow and produce toxins even in pasteurised milk (Holsinger, Rajkowski and Stabel, 1997; Hudson, Wong and Lake, 2003; Claeys *et al.*, 2013).

Thus, even pasteurised products can potentially cause harm to human health, but the greatest health risks are seen in contexts where pasteurisation is not the norm, where hygiene standards along dairy value chains are poor, and where refrigeration and cold chains are largely absent. Such contexts are common in developing countries, particularly in the informal sector.

1.5 Research questions and thesis structure

The dairy trade in Tanzania is a growing sector. Annual national milk consumption steadily increased from circa 17kg per capita in 1980 to circa 22kg per capita in 2002 (FAO 2005). There are two broad groups of dairy cattle in Tanzania: indigenous breeds such as the Tanzanian Shorthorn Zebu, which produce low quantities of milk and are farmed extensively in large herds, and “improved” dairy cattle (cattle which are pure or cross-bred high-producing breeds such as Friesian, Holstein and Jersey) farmed by smallholder farmers who each have small numbers of cattle (Njombe *et al.*, 2011). While the indigenous

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[1] Vegetative bacteria are in a state in which they can grow and reproduce. Sporulated bacteria are unable to grow or reproduce, but sporulation can help them to survive in an environment that is unfavourable for growth. *Bacillus cereus* is an example of a bacterium that can exist in both sporulated and vegetative forms

breeds account for around 70% of milk produced nationally, the number of improved breeds is growing rapidly, increasing threefold from around 200,000 in 1995 to around 600,000 in 2008 (Njombe *et al.*, 2011; Tanzania Ministry of Agriculture Food Security and Cooperatives *et al.*, 2012). An estimated 90% of milk is marketed informally, and only 2% processed (i.e. formally heat treated) (International Livestock Research Institute and East Africa Dairy Development/Tanzania Dairy Survey, 2012; TechnoServe, 2012). Kilimanjaro has the highest density of improved dairy cattle of all regions in Tanzania and produces about 7% of all milk nationally (Tanzania Ministry of Agriculture Food Security and Cooperatives *et al.*, 2012).

Studies conducted in Kilimanjaro region have shown that bacterial zoonoses are the cause of a large proportion (>26%) of cases of febrile illness among patients hospitalised at Kilimanjaro Christian Medical Centre (KCMC) and Mawenzi hospitals in Moshi Municipality, the regional capital, posing a much higher burden than previously recognised (Crump *et al.*, 2013). Risk factor analysis of brucellosis cases from this study population indicated that people living within Moshi Municipality were at higher risk than people living in rural areas of the region (Cash-Goldwasser et al. *in press*). In a case-control study investigating factors associated with brucellosis in rural, peri-urban and urban areas of Kampala, Uganda, Makita *et al.* (2008) found that brucellosis patients were more likely to be resident in urban areas. Brucellosis in Sub Saharan Africa has traditionally been associated with pastoralism, where humans have direct exposure to large numbers of cattle (McDermott and Arimi, 2002; Schelling *et al.*, 2003; Ari *et al.*, 2011; Mai *et al.*, 2012). The suggestion that urban residency may be emerging as an additional risk factor for brucellosis may indicate the changing dynamics of foodborne disease risk as urbanisation progresses. FBD in developing countries may be transitioning from a risk associated with the consumption of locally produced ASPs to a situation where increasingly complex value chains bring contaminated products from far afield into urban areas, putting urban consumers at heightened risk of illness compared to their rural counterparts.

Table 1-1 Human pathogenic bacterial organisms/toxins potentially present in raw cow milk and the diseases they cause

Information is compiled from Claeys *et al.* (2013) and the Control of Communicable Diseases Manual – 19th Edition (2008) unless otherwise stated
***During/after milking**
X= Yes; (X)=Yes, rarely
[a]Only certain strains of *E.coli* that are transferred by cattle, which contain a human-virulent combination of virulence factors and that are pathogenic to humans. Strains of the serotype O157:H7 are the most frequently reported, but strains of other serotypes can result in human cases as well (e.g. O26, O91, O103, O111, O121 and O145)
[b] Potentially zoonotic
[c]Only *Y. enterocolitica* biotypes 1b, 2, 3, 4, and 5 are pathogenic to humans

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
GASTROINTESINAL DISEASE							
Salmonella spp	Most commonly acute enterocolitis, with sudden onset of headache, abdominal pain, diarrhoea, nausea and sometimes vomiting. Fever almost always present.	Usually 12-36 hours; range 6-72 hours.	100-1000 organisms usually required to cause infection, although for several serotypes a few organisms are sufficient. All age groups potentially affected.	(X) (*S.* Dublin)	(X)	X	X

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Human pathogenic verocytogenic *Escherichia coli*[a]	Diarrhoea ranging from mild and non-bloody stools to stools that are virtually all blood. The most severe clinical manifestation is Haemolytic Uraemic Syndrome (HUS), a disease characterized by a triad of haemolytic anaemia (anaemia caused by destruction of red blood cells), acute kidney failure (uraemia), and a low platelet count (thrombocytopenia).	2-10 days, with a median of 3-4 days.	The infectious dose is very low. Little is known about differences in susceptibility and immunity, but infections occur in persons of all ages. Children under 5 years old are most frequently diagnosed with infection and at greatest risk of developing HUS. The elderly also appear to be at increased risk of complications.			X	X
Campylobater coli and *jejuni*	Enteric disease of variable severity characterized by diarrhoea (frequently with bloody stools), abdominal pain, malaise, fever, nausea and/or vomiting.	2-5 days with a range of 1-10 days depending on dose ingested.	Immune mechanisms are not well understood, but lasting immunity to serologically related strains follows infection. In developing countries most people develop immunity in the first 2 years of life.			X	X

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow’s blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Mycobacterium avium subsp *paratuberculosis*[b]	Has been suggested as the causative agent of Chron’s disease, an inflammatory bowel disease that can cause abdominal pain, diarrhoea (which can be bloody), diarrhoea, and weight loss.	Unknown	Unknown	X		X	X
Yersinia enterocolitica[c]	Symptoms of yersiniosis can vary depending on the age of the person infected. In young children, common symptoms are fever, abdominal pain, and diarrhoea, which is often bloody. Symptoms in older children and adults may include fever and pain on the right side of the abdomen (Centers for Disease Control and Prevention, 2016).	Usually 4-7 days.	Children are infected more often than adults.		X		X
Yersinia psuedotuberculosis	Abdominal pain and fever (Jani and Chen, 2013).	Usually 5-10 days.			X	X	X

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Bacillus cereus	An intoxication characterized in some cases by sudden onset of nausea and vomiting, and in others by colic and diarrhoea. Illness generally persists no longer than 24 hours.	30 minutes to 6 hours in cases where vomiting is the predominant symptom; 6-24 hours where diarrhoea predominates.	Unknown.				X
Enterotoxin producing *Staphylococcus aureus*	An intoxication of abrupt and sometimes violent onset, with severe nausea, cramps, vomiting and prostration, often accompanied by diarrhoea and sometimes with subnormal temperature and lowered blood pressure.	30 minutes – 8 hours, usually 2-4 hours.	Most people are susceptible.		X		X
FEBRILE ILLNESS							

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Brucella abortus	Brucellosis: Acute or insidious onset; continued, intermittent or irregular fever of variable duration; headache; weakness; profuse sweating; chills; arthralgia; weight loss; depression; generalised aching. May last days, months, or occasionally a year or more.	Variable and difficult to ascertain; usually 5-60 days, 1-2 months is commonplace, occasionally several months.	10-100 organisms required to cause infection. Severity and duration of clinical illness vary.	X	(X)		X

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Listeria monocytogenes	Usually causes a mild febrile illness, but can cause meningoencephalitis and/or septicaemia in newborns and adults. In pregnant women infection may cause preterm delivery and foetal infection; infants may be stillborn or born with septicaemia or meningitis.	Variable, and longer than most common foodborne pathogens. Cases have occurred 3-70 days after ingesting an implicated product. Estimated median incubation is 3 weeks.	Dose-response relationship is debated. Foetuses and newborns are highly susceptible; infection in children and young adults generally cause less severe disease than in the immunocompromised and the elderly.	X	X	X	X
Leptospira	Varied manifestations. Severity of illness ranges from asymptomatic, to a mild self-limiting febrile illness, to fulminant fatal disease.	5-14 days, with a range of 2-30 days.	Susceptibility is general; serovar-specific immunity follows infection but this may not protect against infection with a different serovar.	X			X (urine)

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Coxiella burnetii	Q fever: an acute febrile disease; onset may be sudden with chills, retrobulbar headache, weakness, malaise, and severe sweats. Considerable variation in severity and duration: infections may be inapparent or present as a nonspecific fever of unknown origin. Chronic Q fever manifests primarily as endocarditis; other rare clinical syndromes, including neurological syndromes, have been described.	Dependent on size of infecting dose; typically 2-3 weeks, range 3-30 days.	Just one organism can cause infection. Susceptibility is general.	X		X	X
OTHER							
Mycobacterium bovis	Bovine tuberculosis: fever, night sweats, weight loss, other symptoms dependent on where the infection is in the body e.g. cough, abdominal pain, diarrhoea.	Variable. Less than 10% of infected people may develop disease; half of those will be within 2 years of infection but latent infection can be lifelong.	Risk of infection is directly related to degree of exposure and less to genetic or other host factors. The risk of developing infection is highest in children under 3, lowest in school-age children, and high again among adolescents, young adults, the very old and the immunocompromised.	X		X	X

Pathogen	Diseases caused	Incubation period	Susceptibility	Source of contamination of milk			
				Direct from cow's blood to milk in udder	Mastitis (udder infect-ion)	Faecal/ skin contam-ination*	Environ-mental sources
Type B toxins of *Clostridium botulinum*	Classic pattern of flaccid, symmetric, descending paralysis. In infants, botulism ranges from a mild illness with gradual onset that never requires hospitalisation, to sudden infant death.	12-36 hours, but sometimes several days.	Infant botulism is the most common form, affecting children under 12 months of age, believed to be because normal bowel flora that can compete with *C. botulinum* have not been fully established.	X (toxins)		X (spores)	X (spores)
Corynebacterium pseudotuberculosis	Human infection is a rare occurrence but has been reported to cause human lymphadenitis including necrotising granulomatous lymphadenitis and eosinophilic pneumonia (Keslin *et al.*, 1979; Mills, Mitchell and Lim, 1997; Peel *et al.*, 1997).	Unknown	Unknown	(X)	(X)		
Streptococcus zooepidemicus	Human infections are rare but have been recorded as causing septicaemia, pneumonia, meningitis, endocarditis, pericarditis, mycotic aneurysm, and post-streptococcal glomerulonephritis (Barnham, Ljunggeren and McIntyre, 1987).	Unknown	Unknown		X		

My research aimed to explore FBD risk in an urban, developing country setting through examining the risks posed by dairy product consumption to residents of Moshi Municipality, Kilimanjaro, Tanzania. My research questions were as follows:

1. What were the patterns of dairy product consumption and acquisition amongst residents of Moshi Municipality?
2. How were the dairy value chains supplying dairy products to Moshi Municipality structured, and how did this structure foster vulnerability to FBD risk?
3. What factors influenced how the dairy value chains functioned, and how did these factors potentially affect FBD risk?
4. At what points and why was FBD risk most likely to be occurring in the chain and how might this impact on consumers?

Chapter 2 of the thesis introduces the Methodology for this research, discussing in particular the value chain risk assessment (VCRA) approach I employed to address questions of disease risk. Chapter 3 addresses the first research question, drawing on work with residents of Moshi Municipality to explore their dairy product consumption and acquisition patterns. Chapter 4 addresses the second research question, describing the structure of the principal value chains supplying dairy products to Moshi Municipality and highlighting the vulnerabilities to disease risk inherent in this structure. Chapter 5 addresses the third research question, providing detailed analysis of the dairy value chains in terms of governance, economics, knowledge flow and adaptation, and how this could relate to FBD risk. Chapter 6 integrates the findings of Chapters 3-5, together with additional data collected from consumers and value chain actors concerning their disease risk practices and perceptions, in order to address the final research question. Finally, Chapter 7 concludes with a discussion of both the research priorities and policy implications that the thesis has highlighted, together with an evaluation of the strengths and weaknesses of using VCRA as a methodological approach to explore FBD risk in developing country settings.

2 Methodology

2.1 Summary

International standards of risk assessment are applied across the globe to evaluate and mitigate food borne disease (FBD) risk in animal source product (ASP) value chains. However, their application in developing country contexts where ASP value chains are often informal, unregulated and shifting has been limited. Integrating value chain analysis approaches with risk assessment offers the opportunity to apply risk-based approaches to FBD risk evaluation in such contexts. Value chain analysis approaches can help to elucidate the structure of value chains in terms of the processes and stakeholders involved, as well as providing valuable bottom-up contextual information regarding the socio-economic, institutional and cultural factors that underpin chain function and potentially drive FBD risk. The “whole chain” ethos of value chain analysis fits well with the “stable to table” ethos of food safety measures (Seimenis and Economides, 2003), and considering all participants in a chain can help to ensure that proposed FBD mitigation measures are equitable and proportionate to risk. Despite these potential benefits arising from a “value chain risk analysis” approach to FBD risk, to date there is no overarching framework expounding how to implement such an approach. In this chapter, I propose a conceptual framework for livestock value chain analysis and present how this can be integrated into a risk pathway approach to qualitatively assess FBD risks. I then apply this framework empirically to investigate FBD risks along dairy value chains in Moshi Municipality, and conclude by considering the idiosyncrasies of the data I collected during the research owing to questions of positionality and working in a second language, and how these idiosyncrasies impacted on my findings.

2.2 An introduction to value chain risk analysis

Across the globe, food borne disease (FBD) risks arising along food value chains are evaluated through a standard international risk analysis framework codified by the World Organization for Animal Health (OIE) and Food and Agriculture Organization (FAO) (OIE 2004b; OIE 2004a; OIE 2010; FAO 2011). The framework consists of four components: hazard identification, risk assessment, risk management, and risk communication. Hazard identification involves identifying agents that are potentially harmful to human health. Risk assessment is the systematic evaluation of evidence to assess the probability of an adverse outcome occurring as a result of a hazard, and the potential negative impact that such an adverse outcome could have. Risk is then considered as a product of probability times impact, such that the larger the probability or impact, the higher the risk. Risk management uses information from the risk assessment to identify and implement appropriate risk mitigation and reduction measures. Finally, risk communication involves communication both of risks and risk mitigation measures to stakeholders, including those who are at risk themselves.

While this risk assessment process is employed as standard across the developed world to evaluate FBD risks, its use in developing countries has been limited, likely due to the difficulty in applying the framework to food systems which are largely unregistered, unregulated and constantly shifting, as opposed to vertically integrated, well-documented and highly regulated food systems of developed countries (Grace *et al.*, 2008; Costales, Pica-Ciamarra and Otte, 2010). However, the result is that little is known about where, how and why FBD risk arises along food value chains in developing countries. In recent years, value chain risk analysis (VCRA) has been advocated as a methodological approach to address questions of animal and zoonotic disease risk (including FBD risk) within livestock systems (FAO 2011). VCRA seeks to generate an understanding of livestock production systems and how stakeholders operate within them through value chain analysis, and combine this with epidemiological risk analysis to evaluate the disease risks within the livestock production system and identify measures to reduce those risks (Rushton et al. 2009b). The approach posits that in order to understand how a disease might arise and spread within an animal source product (ASP) food system, it is necessary to understand both how the system is structured and the activities that are undertaken within it.

Value chain analysis itself originated in the field of business strategy as an analytical approach to identify ways to improve market efficiency (Rich et al. 2011a; Kaplinsky & Morris 2000; FAO 2011). There are various definitions of what constitutes a value chain: for example "the full range of activities required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation) and the input of various producer services), delivery to consumers, and final disposal after use" (Kaplinsky & Morris 2000, page 4); "the activities required to bring a product from its conception to the final consumer" (Mccormick & Schmitz 2001, page 17) and "groups of people linked by an activity to supply a specific commodity" (FAO 2011, page 7). Common to all definitions is the idea of characterising how a value chain is structured from product conception through to consumption, and describing the activities that are undertaken in order for the chain to function to produce the final product.

Integrating value chain analysis with risk assessment offers several potential benefits as a methodological approach to assessing FBD risks in developing country contexts. Firstly, value chain analysis can serve to provide data on the structure of the value chains supplying food to consumers where few such data may exist. Informal producers and traders, by virtue of their informality, may fall under the radar of regulatory authorities; this coupled with the increasing length and complexity of ASP value chains can result in there being no clear picture of where the ASPs supplying consumers originated and how they travelled from stable to table. One of the first steps of value chain analysis is to map the value chain, providing valuable information on the groups of actors involved in the chain, how they are interlinked, and how this might relate to disease risk and mitigation (Rich & Perry 2011; FAO 2011). For example, recent work to map meat value chains serving Nairobi, Kenya, revealed that two specific meat markets dominated the supply of beef and small ruminant meat, both of which had previously been identified as foci for illegal activities and food safety risks (Alarcon *et al.*, 2017). The study showed that, given the economic and social importance of these markets, any future interventions or policies aiming to improve food safety and security to the city will not succeed unless they are designed with these markets at the forefront. In 2007 during continuing outbreaks of Highly Pathogenic Avian Influenza (HPAI), FAO initiated a series of value chain studies in Asia and Africa in order to gain a better understanding of the trade flows, disease transmission mechanisms and possible entry points for intervention in the value chains (Mcleod *et al.*, 2009). Through working with key government informants and value chain actors (e.g. farmers, poultry shops and slaughterhouses), the studies collectively built a clear picture of the structure of the poultry sector and the relationships between the people and institutions involved. This served as a framework from which possible disease mitigation strategies could be discussed. For example, in Northern Sumatra, breeders were identified as an important intervention point for the entire duck industry, as they supplied young ducks to both the industrial and smallholder systems present in the country. Rushton *et al.* (2009) reported similar benefits of using a value chain approach when considering HPAI risk reduction in the Greater Mekong Sub-region. Mapping the various poultry commodity value chains (e.g. chickens, ducks, eggs) both strengthened the understanding of the movement, seasonal, and geographical elements of the value chains and the people involved, and also helped identify which points along the chain required risk reduction actions.

Secondly, value chain analysis generates important contextual data relevant to the setting in question. Responses to animal diseases in the developing world are often modelled on those in more developed settings, as researchers and policy makers in the developing world are often influenced and/or trained from such perspectives (Rich and Perry, 2011). This can potentially lead to disease control strategies that focus on disease elimination at the expense of other crucial contextual issues, such as the importance of value chain participation as a livelihood for the poor, or the cultural value held by livestock in addition to their financial value. Using value chain analysis approaches in disease risk assessment can help avoid such pitfalls, by providing information not just on risk but on the socio-economic, cultural and institutional factors that modulate and drive risk. Insights can be gained into the different ways in which participants in the value chain are affected by and react to disease hazards, and the competing narratives, perceptions and acceptance of risks (FAO 2011). The integration of contextual information means that VCRA can help generate hypotheses regarding not just *where* risk might be occurring, but also *how* and *why*.

The third benefit of VCRA is an extension of the contextual benefit just described: namely, VCRA requires “bottom-up” participatory approaches which eschew a normative mind-set (i.e. attempting to provide guidance on how participants in the value chain *should* behave) in favour of uncovering instead how those participants *actually* behave (Rich & Perry 2011; FAO 2011). Participatory approaches allow voices to be heard from actors who were historically not approached and whose views were not systematically sought, such as those of participants in informal value chains (Rich and Perry, 2011).

Drawing on research into FBD risk assessment in urban African settings, Grace *et al.* (2008) have highlighted the strengths of participatory approaches in providing data on food hazards, exposure assessment and risk characterisation. Such bottom-up, non-normative approaches acknowledge that the manner in which value chain actors respond to questions of disease risk is contextualised by their unique set of circumstances and constraints (Rich and Perry, 2011). Ultimately these insights lead to more effective policy making in the area of FBD control, by recognising what risk management interventions might be feasible and what actions might be needed to encourage compliance. For example, Rich *et al.* (2009) used a VCRA approach to investigate HPAI risk in Nigeria in 2006-2007, and found the risk of disease transmission was strongly linked to economic incentives for chain actors to choose riskier commercial practices. There were several manifestations of this, such as traders mixing poultry species in cages to reduce their costs. The increased disease risk as a result of this practice was only of secondary concern to these traders when compared to the cost savings. In light of these insights, the authors concluded that compliance with proposed disease outbreak control measures may require the development and administration of funds that members could draw from in order to compensate for the economic penalties such measures would create.

The final strength of VCRA is its “whole chain” approach, characterising the value chain from production to consumption and considering what, how and why disease risks arise along its entire length. This is advantageous for two reasons. Firstly, it offers opportunities to identify risk hotspots and critical control points for intervention throughout the chain. It is a central tenet of food safety that disease risk mitigation measures should be implemented “from stable to table”; multiple interventions at multiple points along the chain collectively serve to reduce the final risk to consumers (International Livestock Research Institute 2012; World Health Organization and FAO 2011). Secondly, it offers the opportunity to consider how decisions made at one stage in the chain might impact the activities of actors elsewhere in the chain. For example, through using a value chain methodology to examine the impact of a Rift Valley Fever outbreak in Kenya in 2006-2007, Rich and Wanyoike (2010) demonstrated that disease control methods implemented in the outbreak had far reaching consequences in the meat value chains, causing significant losses to livestock traders, slaughterhouses, casual labourers and butchers, with many reporting that they were unable to go back into business after the outbreak was over. However, state investment during the outbreak tended to focus on compensating the impact felt by producers, overlooking these other severely affected groups. Thus, the whole chain approach of VCRA can assist in ensuring that disease mitigation strategies are more equitable and proportionate to risk. This is particularly important in developing country contexts, where strict efforts to enforce food safety standards along ASP value chains has the potential to deprive communities both of an important source of nutrition derived from those ASPs, and of the livelihoods that derive from participation in those value chains (Global Panel on Agriculture and Food Systems for Nutrition, 2016b).

2.3 Value chain analysis: conceptual framework

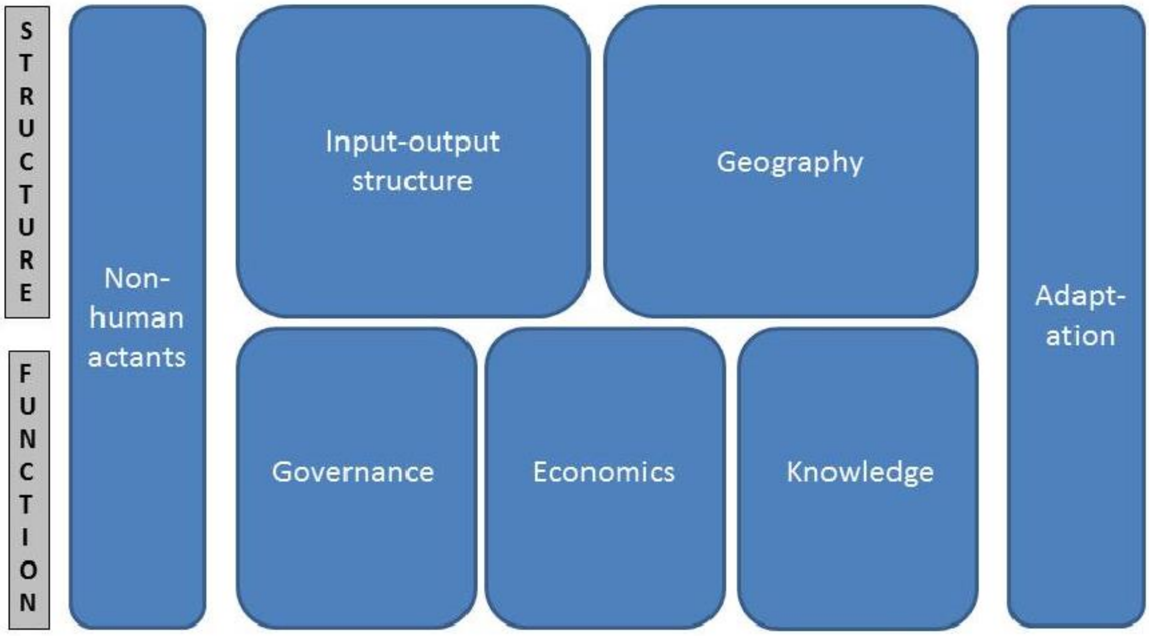
There are no established rules and conventions as to how to conduct a value chain analysis. In the development sphere, value chain analysis has primarily been applied as a methodology to understand markets in the developing world, in order to provide the information needed to design and implement appropriate development programmes (Rich et al. 2009a). The manuals and toolkits that do exist tend to be concerned with international exports rather than domestic value chains, and to focus on ways to maximise chain efficiency or to identify points where poor people can join or "upgrade" as participants in the value chain (Kaplinsky and Morris, 2000; Mccormick and Schmitz, 2001; Springer-Heinze, 2008). Moreover, these manuals often concern value chains relating to goods other than ASPs, and thus overlook the peculiarities specific to livestock value chains (e.g. movements of animals or perishability of products). In 2011, FAO published a manual specifically concerned with integrating value chain analysis into disease risk assessment (FAO 2011). However, although very detailed, this manual offers no useful conceptual overview of what comprises a livestock value chain and what a livestock value chain analysis should examine. Therefore, for this research, I reviewed the existing value chain literature to develop a terminology and conceptual framework for a livestock value chain analysis which is specifically intended to be integrated with disease risk assessment.

The terminology is presented in Table 2-1 and is based on terms expounded by Bolwig & Ponte (2010) unless otherwise stated. The conceptual framework is presented in Figure 2-1. It expands on the idea put forward by McCormick & Schmitz (2001) in their value chain manual for the garment industry, in which a value chain is conceptualised as consisting of three different dimensions: the input-output structure, geographic spread, and governance. I found the delineation of different dimensions to be a useful starting point, but that the model proposed was too simplistic. The conceptual framework I developed consists of expanded definitions of McCormick & Shcmitz's three original dimensions, plus four additional dimensions: economics, knowledge, non-human actants, and adaptation. I will describe each of these dimensions below.

Table 2-1 Terminology for dairy value chain analysis in Moshi Municipality

Term	Definition
Value chain	the full range of activities which are required to bring a dairy product from the point of initial milking to consumption in Moshi Municipality, including the different phases of processing, physical transformation, and delivery and retail to final consumers (Kaplinsky and Morris, 2000)
Value chain actor	someone who has a direct role in the production, purchase or sale of the dairy products consumed in Moshi Municipality; for example, farmers, traders, shopkeepers, and also employees at dairy processing units (DPUs) and milk collection centres (MCCs), and consumers
External actor	an individual or organisation that does not directly handle the dairy product but that provides services, expertise or exerts influence on the dairy value chain. This includes legislative bodies, animal health services, government officials, non-governmental organisations and stakeholder groups
Node	a point in the value chain at which a dairy product is exchanged, i.e. purchased or sold. For example, a DPU is a node: milk is purchased by the DPU, processed, then sold. Several value chain actors may work at the DPU i.e. there are more value chain actors in a value chain than there are nodes
Strand	value chains have different strands owing to different product characteristics; institutional configurations; or different origins of production or end-markets. Strands of the dairy value chain might include, for example, milk, cheese and yoghourt. Each strand can be expected to involve different nodes and actors to varying degrees

Figure 2-1 Value chain analysis: conceptual framework



1. **Input-output structure**

   McCormick and Schmitz (2001) define the "input-output structure" as the sequence of processes that make up a value chain. For a dairy value chain, this means the sequence of processes that occur from initial milking to consumption – for example, milking → processing → transport → wholesale → retail → consumption. I found this definition to be limited for two reasons: firstly because it overlooks the value chain actors and nodes involved in a value chain, and secondly because it fails to capture the context in which those processes are taking place.

   I therefore add to this definition to further consider the input-output structure to describe which nodes are involved in a value chain, how these nodes are linked together, which value chain actors participate at each node, and how these actors are related to each other. Characterising the input-output structure in this way facilitates the crucial first step in any value chain analysis: value chain mapping (Kaplinsky & Morris 2000; Mccormick & Schmitz 2001; Springer-Heinze 2008; FAO 2011). Mapping provides visual representations of the sequence of processes that make up the value chain, and of how value chain nodes are related and interlinked. These graphics can then be used as heuristic tools to enable further interrogation of the value chain.

However, I draw again on the work of Bolwig & Ponte (2010) to ensure that my characterisation of the input-output structure goes further than the simplistic description and graphical representation of linkages. Importantly, I give attention to what can be termed “horizontal” and “vertical” aspects of the chain. Bolwig & Ponte (2010) note that the use of the term value “chain” fosters a focus on “vertical” relationships, that is, the sequence of relationships between suppliers and buyers that results in a commodity moving from producer to consumer. They argue that such a focus overlooks the local context within which value chain actors and their communities are situated. These local contexts correspond to what they term the “horizontal” elements of the chain, and comprise factors such as poverty, gender and the environment. Identifying and characterising the horizontal elements of a value chain can be critical to understanding how and why value chain actors participate in that chain at each particular node, and what are the costs and benefits to them of doing so. Actively incorporating a focus on the horizontal elements of the input-output structure is thus a critical step towards understanding chain function.

Finally, I include in this dimension the approximate number of actors participating at each node, and the quantities of product flowing through each node. This helps to give an overview of the key players participating in a value chain, as well as where bottlenecks may occur.

2. **Geography**

McCormick and Schmitz (2001) define this dimension simply as the degree of geographic spread of a value chain, i.e. whether the reach of a value chain is local, regional, national or global. Mindful of the contrast between the mountainous rural villages surrounding and supplying milk to the lowland area of Moshi Municipality, I expand on the former definition by describing the spatial properties of value chain nodes in terms of both location *and* topography. Furthermore, I draw on the perspective of time-geography (a methodological approach that considers the temporal and spatial aspects of processes and events together rather than in isolation (Lenntorp, 1999)) to describe the temporal aspects of the value chain, such as how long it typically takes for a commodity to travel from one node of the value chain to the next and what factors might affect those timings. This dimension draws attention to the time that a commodity takes as it progresses along a value chain towards the final consumer, a critical issue for ASP value chains where products are perishable, and where long chains may facilitate the proliferation of bacterial pathogens.

3. **Governance**

   There has been much discussion in the value chain literature surrounding how governance is defined and examined. However, much of the discussion and proposed definitions centre around global value chains involving powerful companies, international trade deals, and high degrees of regulation (Kaplinsky & Morris 2000; Gereffi et al. 2005) These concepts and definitions of governance do not accord well with the domestic, largely informal dairy value chains that supply Moshi Municipality. Therefore, in this thesis I use a simpler definition of governance as outlined by McCormick and Schmitz (2001). These authors note that actors in a chain both directly control their own activities, and are directly or indirectly controlled by other actors. I define the governance dimension as the degree of influence and control that value chain actors can exert along the value chain, and the power dynamics that create and arise from this.

4. **Economics**

   Economics are clearly central to how a value chain functions and merit consideration as a specific dimension. I define this dimension as having three aspects: first the monetary value added to a dairy product as it progresses along the chain; second, the factors that govern prices; and third, the profitability of participating in the value chain. The first aspect entails tracing purchase and sale prices along the value chain. This reveals the monetary value added at each node and enables price comparisons between different value chain actors. It is important, however, to recognise that prices are not fixed and may vary throughout the year, for example depending on season, and to collect information in a manner that reflects this. This ties in with the second aspect: examining what factors govern prices. This includes factors that play out at a local level (for example, at each point of exchange, how is the sale price negotiated between buyer and seller). It also covers factors that play out at a broader level, such as the knock-on effects of inflation or oil prices. The third aspect examines the profitability of participating in the value chain both at an individual level (i.e. as a value chain actor) and at a community level (i.e. the benefits and costs to the community of being integrated into the dairy industry). These profits and costs may not be solely monetary; for example a non-monetary benefit could be increased women's empowerment as a result of being active participants in the dairy value chain.

5. **Knowledge**

   Value chain actors each require specific knowledge, expertise and skills to carry out the activities that they are responsible for in the value chain in order for a commodity to successfully progress from one node to the next (Mccormick and Schmitz, 2001). This dimension explores not simply what knowledge is required, but also how knowledge is generated. It also examines the barriers that exist to developing knowledge that could help the value chain function more efficiently and effectively.

6. **Non-human actants**

   The term *actant* denotes both humans (ie, *actors)* and non-humans. According to actor-network theory, non-human actants themselves have the capacity to act and participate in systems and social networks (Latour, 2005). Put another away, non-human actants themselves have agency (independently of humans) and are thus able to influence how a system, such as a value chain, functions. For example, changing technologies may allow different sorts of connections to be made between value chain actors, enabling different value chain strands to arise as a result.

   Any value chain will inevitably depend on many types of non-human actants to allow it to function: the equipment used for production and processing, the containers used for storage, the vehicles used for transport and distribution, the roads that these vehicles travel along. Moreover, in the context of food value chains, the materials and equipment involved can be pivotal to food safety and perishability. Therefore, non-human actants arguably warrant special attention when analysing food value chains. In reflection of this and to ensure their role is not overlooked, I include them as a separate dimension in the conceptual framework. To my knowledge, consideration of the role of non-human actants in value chain analysis is a novel contribution to the value chain field.

7. **Adaptation**
   Value chains are not static entities; they are constantly evolving as they adapt to changing contexts and environments. This dimension serves to ascertain the factors that both affect and effect change, and identify examples of how the value chain responds to these changes.

It is clear from the descriptions above that the dimensions of the conceptual framework overlap somewhat. For example, non-human actants may exert control over some aspects of the chain, thus contributing to chain governance. Economic changes such as the cost of transport may force value chain actors to adapt and find new markets, changing the chain's input-output structure. Therefore, the seven dimensions of the conceptual framework should not be considered as discrete entities to be considered separately. Rather, the framework reflects that each of these seven dimensions are key characteristics of any value chain, and serves to ensure that each is adequately captured and addressed in a value chain analysis. However, it can be argued that the dimensions broadly fall into two groups: those that primarily describe how a value chain is *structured* (input-output structure; geography), those which describe how a value chain *functions* (knowledge; governance; economics), and those which span both domains (non-human actants; adaptation), as depicted in Figure 2-1.

2.4 Risk assessment

In this research, I focussed on the first two components of the risk analysis process, hazard identification and risk assessment. For an identified hazard to be a risk issue, there must be at least one outcome associated with its presence that could be potentially harmful (FAO 2011). Risk assessment aims to provide a systematic, evidence-based and transparent method to assimilate relevant information to evaluate risk. A key method to link the presence of a hazard to potential adverse outcomes is risk pathway analysis. A risk pathway describes the chain of events that must occur for the final undesired outcome to happen as a result of the presence or introduction of a particular hazard. In this research, I mapped out several risk pathways identified through fieldwork as existing between cow and consumer, and assessed the risks arising along them. The information I collected through value chain analysis was instrumental to this process, in particular the data on input-output structure.

In the risk assessment process, a question is posed at each step of a risk pathway as to the probability of the event in question occurring, and the potential impact should that event occur. Taking account of the available data and information, the risk assessor estimates this probability and impact and calculates risk as a product of the two paramaters. Risk assessment can be quantitative or qualitative. In a quantitative risk assessment, numerical estimates of risk are calculated mathematically as the product of probability and impact, where each parameter is estimated as a figure between 0 and 1. In qualitative risk assessments, probability and impact are defined as discrete qualitative categories, and a risk matrix employed in order to consider each together to estimate risk (Figure 2-2). Given the paucity of quantitative data about the Tanzanian dairy industry available to inform numerical estimates, particularly from the informal sector, I judged a qualitative approach to be more suitable for this research. I used information from the literature together with original data regarding value chain structure, function and risky practices in order to make judgements about probability and impact along the risk pathways.

Figure 2-2 Risk matrix used to evaluate risks along dairy value chain risk pathway. Green boxes represent low risk; yellow boxes represent intermediate risk; red boxes represent high risk.

	IMPACT				
PROBABILITY	Negligible	Minor	Moderate	Major	Severe
Very high	Low	Low	Intermediate	High	High
High	Low	Low	Intermediate	Intermediate	High
Medium	Low	Low	Low	Intermediate	Intermediate
Low	Low	Low	Low	Low	Low
Very low	Low	Low	Low	Low	Low

2.5 Limitations of value chain risk assessment

A key critique of risk assessment is that it suggests that risk is an objective, quantifiable entity that can be made known. People's *perceptions* of risk are then framed as (mis)interpretations of the magnitude of that objective risk by lay people who do not possess, or do not recognise, the expert knowledge that has been used to quantify it. Sociologists of risk eschew such framings, arguing that risk is always individual, contextual, and based on personal lived experiences, knowledges and competing priorities (Green, 2009). Zinn (2009) argues that statistical and probabilistic approaches towards risk (such as risk assessment) are limited and reductionist, as they fail to take into account the myriad ways in which risk is socially constructed. For these reasons, he contends that relying on such assessments as a way to understand and respond to risk is problematic. This argument is valid if scientific approaches to risk fail to recognise the constellations of ways in which risk may be framed by different individuals, actors and communities. However, the strength of integrating value chain analysis with scientific risk assessment is that the collection of socio-economic and cultural data allows for such framings to be built into and made part of the findings of the risk assessment itself. As Rich and Perry (2011) argue, applying value chain approaches to disease questions serves to contextualise biological drivers of risk in their socio-economic and institutional settings.

However, the fact remains that the process involved in evaluating risk is ultimately subjective. For all the attempts to systematically tabulate risk input data in a qualitative risk assessment, the decisions a risk assessor makes concerning level of probability and impact are all ultimately judgement calls. No two risk assessors can be guaranteed to make the same decisions, despite the information which is before them (Cox, 2008; Hubbard, 2009; Smith, Siefert and Drain, 2009; Thomas, 2013). Cox (2008) notes that there is no objective way to fill out a risk matrix; categorising probability and impact are inherently subjective judgements, and will depend at least in part on the experiences and risk attitude of the assessor. In analysing risk data from the airline industry, Smith *et al.* (2009) revealed evidence of cognitive biases in the judgement of probability and impact – namely a tendency to centre probability estimates towards medium values, and to overestimate impact. Similar findings were found in risk analyses undertaken in the information technology industry, which showed a tendency for people to avoid extreme values or statements when presented with a choice ("centring bias") (Hubbard, 2009; Thomas, 2013). Both Cox (2008) and Smith *et al.* (2009) note that the degree of subjectivity could be decreased if more data are used to support the decisions (for example, historical data. However, this seems paradoxical given that qualitative risk assessments are often conducted precisely because the data available are sparse. Given that some degree of subjectivity is unavoidable in risk assessment, it can be argued that risk assessments should be accompanied by reflective statements from the risk assessor(s) regarding how their personal characteristics may have affected the production and interpretation of the data used to make the decisions. Such reflexivity is rare in the biomedical sphere, but standard in the social sciences (see discussions on "positionality" in section 592.8.1).

A further critique concerns whether the level of risk calculated through use of a risk matrix consisting of ordinal categories of probability and impact in actuality maps mathematically to the underlying assumed linear risk relationships for which the matrix serves as a proxy. Cox (2008) uses a simple example to demonstrate this. Figure 2-3 shows the simplest type of risk matrix: a two by two table whereby probabilities and impacts are rated either low or high, and risk calculated as low, medium or high depending on the relationship between probability and impact. Mathematically, probability will vary between 0 and 1, such that everything below 0.5 can be considered low risk, and everything above high risk (and the same for impact). If for Risk A the mathematical probability were 0.1 and impact 0.65, this would constitute a quantitative risk of 0.1 x 0.65 = 0.065. Using the qualitative risk matrix, probability is low and impact high, therefore the risk would be rated medium. If for Risk B, probability were 0.37 and impact 0.38, the quantitative risk would be 0.37 x 0.38 = 0.14, substantially higher than Risk A. However, using the risk matrix, both probability and impact are low, so the risk would be rated low. Therefore, the risk matrix would rate Risk B as lower than Risk A, despite the fact that Risk A is in fact higher than Risk B. The example neatly demonstrates that although intuitively risk matrices appear to approximate quantitative risk relationships, this is not always the case. Indeed, in this case, using a risk matrix has led to the incorrect conclusion regarding the level of risk. For this reason, some authors have argued that qualitative risk assessments, rather than aiding decision making, can sometimes lead to outcomes that are in fact less correct or informative than had they been estimated at random (Cox, 2008; Hubbard, 2009; Thomas, 2013).

Figure 2-3 A 2 x 2 Risk Matrix

		Impact	
		Low	High
Probability	High	Medium	High
	Low	Low	Medium

Fortunately, Cox (2008) offers some mathematical fixes to this problem. He defines three conditions for the design of the risk matrix – *weak consistency, betweenness* and *consistent colouring* – which if adhered to can preserve the proxy relationship between the qualitative risk matrix and the underlying quantitative increase in risk, to the extent that the risk matrix can be used as screening tool to distinguish between low and high risks. The mathematical proofs behind these conditions are beyond the scope of this thesis (Cox, 2008); however, the risk matrix that I used for this research (depicted in Figure 2-2) satisfied these three conditions.

2.6 Use of mixed methods

Value chain risk analysis seeks not only to identify potential pathogen transmission risk points, but also to characterise the socio-economic and cultural behaviours and practices driving those risks, in order to understand how and why risks might arise and might best be mitigated. Such a pursuit is of necessity an interdisciplinary endeavour. Drawing on insights as diverse as how actors relate to each other, how governance functions along the chain, how knowledge is generated or impeded, and how prices are set or fluctuate, characterising a value chain requires the use of methods from the social, economic and political sciences. It necessitates the collection of quantitative data, such as purchase and sale prices; volumes of product flowing along the chain; and numbers of value chain actors involved; but also qualitative data providing detailed information regarding how various relationships are established and mediated. Consequently, I employed mixed methods from divergent disciplines throughout the research, including structured and semi-structured surveys, in-depth interviews, group discussions, proportional piling exercises, participant observation, time use analysis, and spatial mapping.

While increasing in popularity as an approach, a universally accepted definition for what constitutes mixed methods research is yet to be agreed (Creswell and Plano Clark, 2011). Johnson *et al.* (2007) summarised mixed methods research thus:

> *"Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the purposes of breadth and depth of understanding and corroboration."*

A hallmark of mixed methods research is therefore the use of both qualitative and quantitative approaches. Qualitative and quantitative methods complement each other, each providing different insights regarding a particular problem. Quantitative data serve to identify the *extent* of a particular issue, whereas qualitative data provide a deep and detailed *understanding* of that issue. Quantitative studies typically involve large numbers of individuals, in order to generate results from a sample that provide an accurate reflection of the true situation in the population, and which facilitates generalisation of findings. However, in so doing detailed understanding at the individual level is lost. Qualitative studies can provide that understanding; however, this is at the expense of generalisability as relatively few individuals are studied. Collecting and analysing both types of data in parallel serves to counterbalance the shortcomings of each approach.

Crewsell and Plano Clark (2011, page 13) note that *"mixed methods research is "practical" in the sense that the researcher is free to use all methods possible to address a research problem"*. I certainly found this freedom invaluable at all stages of the research, as it allowed me to approach the research questions from several angles and attain more comprehensive and complete answers to those questions. For example, at the outset of fieldwork, before I could decide which dairy value chains warranted further investigation, I needed an idea of what dairy products were most frequently consumed by the general population. This question was best answered by quantitative methods. However, to understand how those dairy products were acquired and consumed and why they were favoured required the use of qualitative methods. At the other end of the spectrum, once fieldwork had been completed and I was synthesising the risk analysis, assessing risks required both quantitative estimates of the numbers of value chain actors involved at each stage and the volumes of dairy products traded, as well as qualitative understandings of the relationships and decision-making behaviours occurring along the chains.

2.7 Fieldwork

2.7.1 Study locations and schedule

Tanzania is organised into hierarchical administrative divisions according to the scheme: Region – District – Ward – Village/Street (the term “street” is used in urban settings and “village” in more rural settings). Moshi Municipality district is the capital of Kilimanjaro region. The district comprises an area of around 59km^2 situated in the North East of the region at the base of Mount Kilimanjaro (Figure 2-4). As in many secondary African urban settlements the town is experiencing a high rate of growth, with the population expanding by almost 30% in one decade, from 143,799 inhabitants in 2002 to 184,292 inhabitants in 2012 (Tanzania National Bureau of Statistics and Ministry of Planning Economy and Empowerment, 2006; United Nations Human Settlements Programme, 2008; Tanzanian National Bureau of Statistics, 2013).

Fieldwork was conducted in four stages: two short exploratory phases in April 2013 (three weeks) and July 2013 (ten days), and two longer data collection phases from October 1 – December 20 2013 and April 22 – July 31 2014. Each data collection phase had different objectives. The primary objective of the first phase was to characterise the dairy product consumption and acquisition patterns in Moshi Municipality by conducting research with consumers in the district. For these purposes, we[2] conducted research in eleven Moshi Municipality

[2] “We” refers to the research team: myself, Matayo Melubo and Fadhili Mshana (research assistant and driver respectively in both phases of fieldwork) and Neyeyo Lucumay, research assistant in the first phase of research. I use first person plural for activities we did together, and first person singular for fieldwork decisions I made or analysis I undertook myself.

wards: ten randomly selected with probability proportional to size of the ward population, plus a purposively selected pilot ward (Figure 2-5). A secondary objective was to conduct a preliminary value chain analysis, concentrating principally on input-output structure and geography dimensions.

The second phase of fieldwork (April – July 2014) had the dual objectives of conducting an in-depth analysis of the dairy value chains we had identified, and collecting information pertinent to disease risk at all stages of the chain in order to inform the risk assessment. We concentrated fieldwork in Hai (Figure 2-6), which our earlier fieldwork had identified as the district selling the highest quantity and highest proportion of the dairy products it produced directly to Moshi Municipality. Through key informant interviews (KIIs) with district-level government officials, we identified four wards in Hai as the main milk-producing areas in the district. Following KIIs with officials from these wards, I purposively selected five villages across four of the wards according to the following factors: firstly, the desire to purposively include a “spread” of dairy set-ups within the selection (e.g. wards with and without a Dairy Processing Unit (DPU) or Milk Collection Centre (MCC)); secondly, the presence of a co-operative livestock field officer (LFO) in the ward (ascertained through the level of engagement when setting up and during the KII); and finally, the expectation from the ward LFO that the village would be willing to engage in the research (this often hinged on the personal relationships and level of contact between the ward LFO and the village-level officials).

Table 2-2 List of villages in Hai district selected for dairy value chain risk analysis, second fieldwork phase

Ward	Village	Dairy units
Machame Kaskazini	Wari	DPU
	Foo	DPU, although functioning at time of fieldwork as MCC only
Machame Magharibi	Nronga	DPU (longest established DPU in Hai district)
Masama Kati	Ng’uni	Three MCCs, all with collection tanks (plus another MCC under construction)
Masama Mashariki	Mudio	None; milk taken to Moshi Municipality by intermediary traders only

Figure 2-4 Map depicting Kilimanjaro region, including Moshi Municipality and Hai districts, North East Tanzania
Map prepared by Mike Shand, School of Geographical and Earth Sciences, University of Glasgow

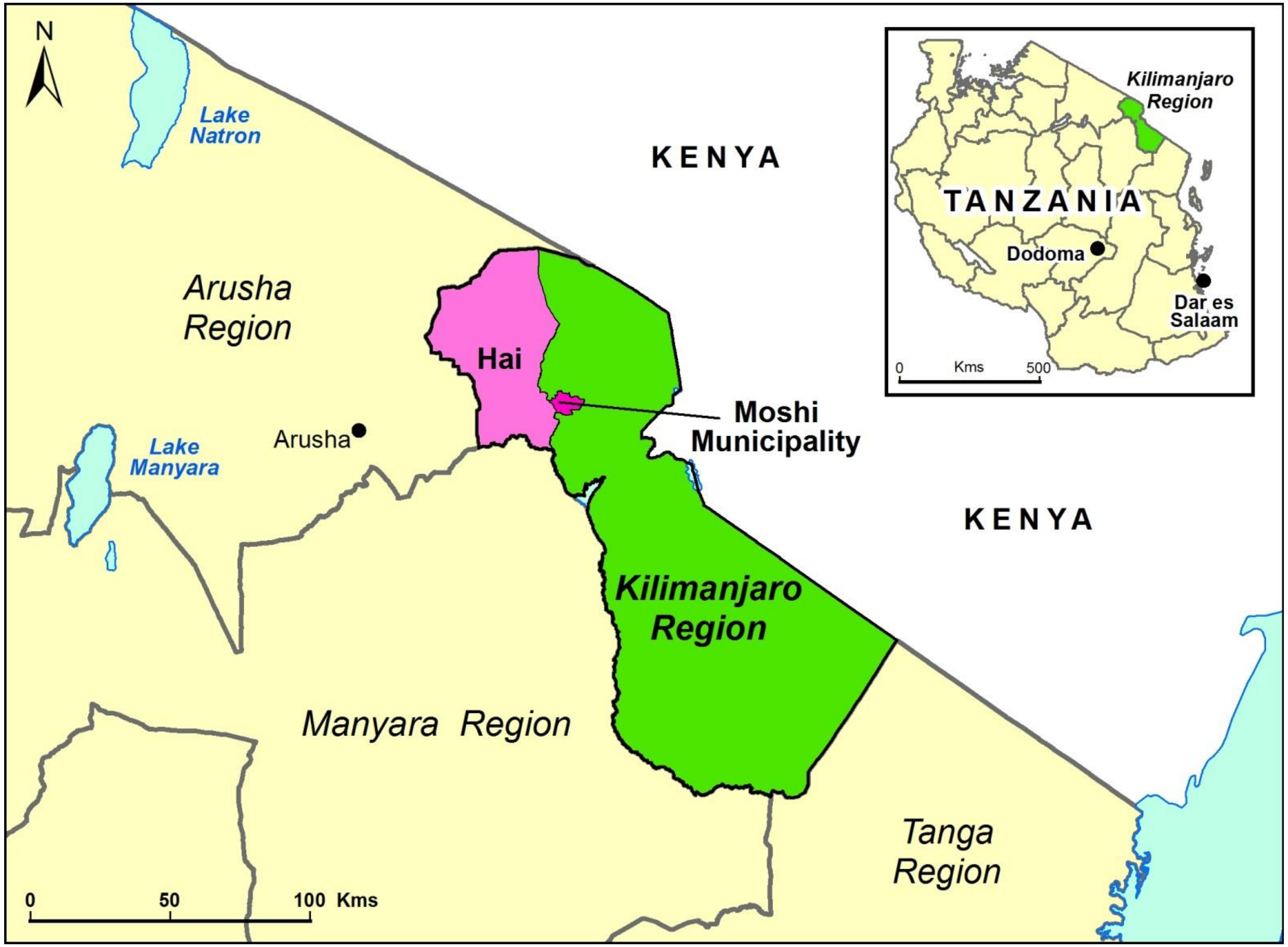


Figure 2-5 Map of Moshi Municipality with selected study wards

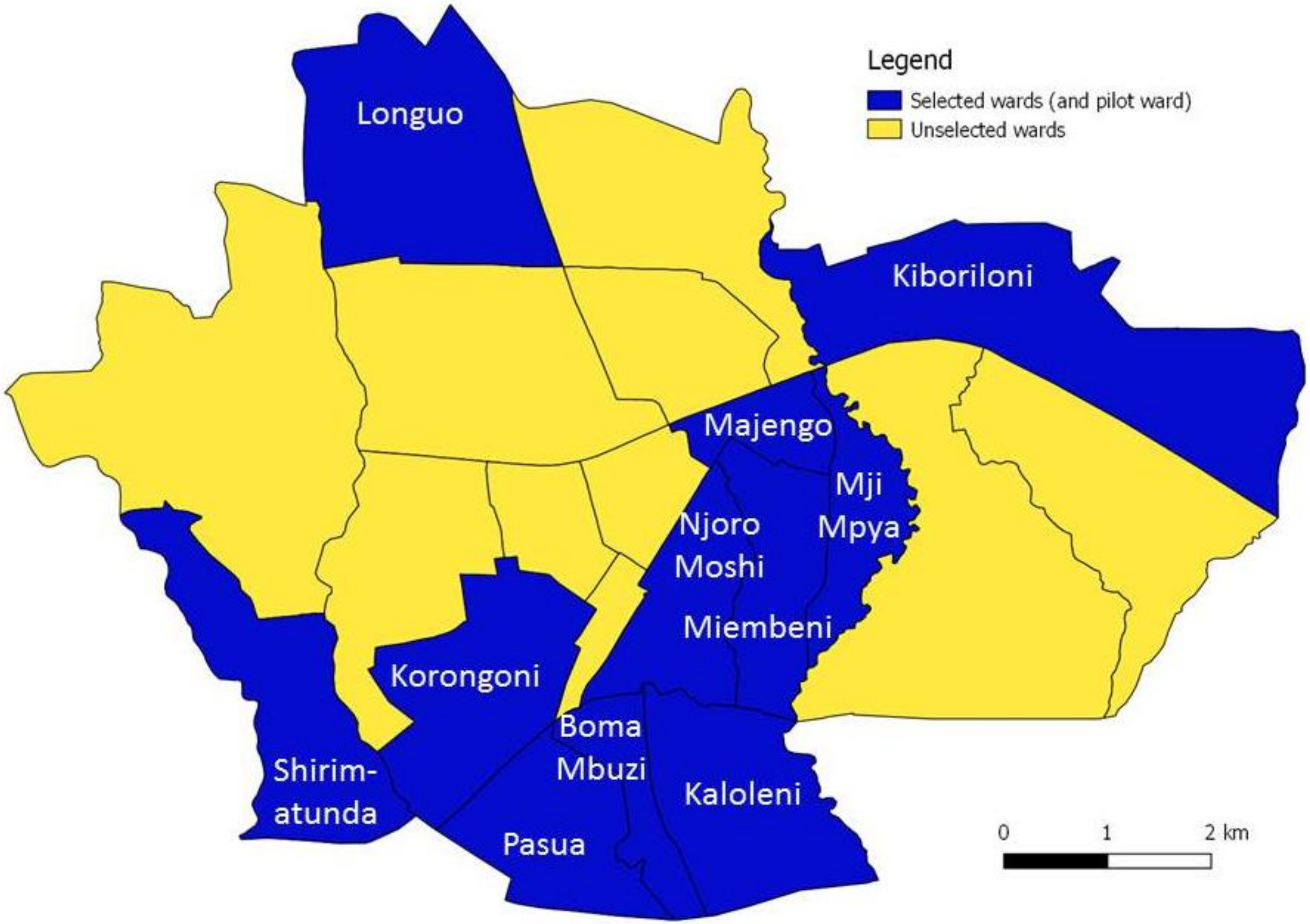
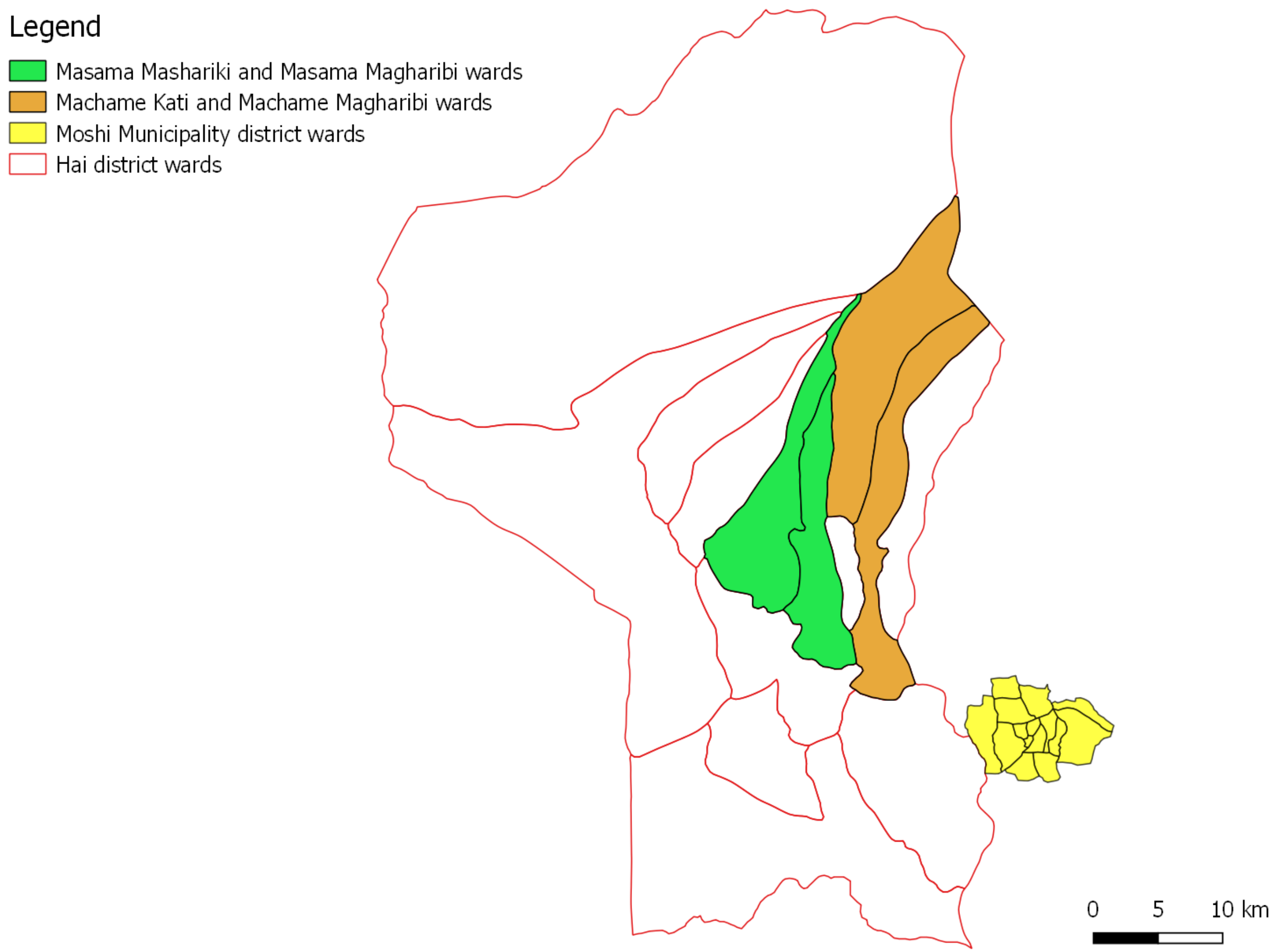


Figure 2-6 Study wards in Hai district selected for second data collection phase



During both the first and second fieldwork phases, we also collected value chain risk assessment data within Moshi Municipality at points of dairy product sale. This included Kiborilonі market (visited weekly), various locations where intermediary traders sold their milk, local shops, and at the homes of urban cattle keepers.

2.7.2 Ethics

The study was independently reviewed by the Ethics Committee of the College of Medical, Veterinary and Life Sciences (MVLS), University of Glasgow. Locally, ethical approval of the study was covered by two Tanzanian committees as part of the umbrella project entitled *"The Impact and Social Ecology of Bacterial Zoonoses in Northern Tanzania"* (Kilimanjaro Christian Medical Centre Ethics Committee, Moshi, Tanzania – Proposal no. 503) and National Institute of Medical Research, Tanzania – reference number NIMR/HQ/R.8a/Vol. I obtained a Tanzania Commission for Science and Technology (COSTECH) research permit and Class C resident's permit for the duration of the research period.

Both of my research assistants, Matayo Melubo and Neyeyo Lucumay, and my project driver Fadhili Mshana had relevant prior research experience. I developed a bespoke ethics training programme for all of the team based on materials from the Collaborative Institutional Training Initiative (CITI), which they completed before we commenced fieldwork. The programme covered issues that were particularly relevant to the research, such as informed consent and maintaining confidentiality.

The adult literacy rate in Tanzania was approximately 68% at the time of research (UNICEF, 2013). To ensure informed consent, we read out information from standardised information sheets to all potential participants, examples of which can be found in Appendix 1. All participants were offered hard copies of the information sheet to retain, and given the opportunity to ask questions and seek clarifications. The exception to this was key informant interviews, wherein the information sheet was replaced by an introductory letter addressed to the informant. This letter explained more explicitly that the research aimed to investigate links between dairy product consumption and infectious disease risks (the information sheets referred more generally to the links between dairy products and “health”, so as to avoid unduly influencing participants’ responses to research questions).

For group discussions, in-depth interviews and other qualitative research methods, we obtained verbal consent to participate and consent to record proceedings by audio tape and/or written notes prior to commencing. I considered verbal consent preferable to written consent in order to maintain an informal, unthreatening environment, and to avoid identifying and potentially stigmatising illiterate people in front of their peers. In the case of the consumer survey, which involved a more formalised process using a standardised questionnaire administered in participants’ homes, we sought written consent. Participants unable to sign were able to consent by fingerprint.

No research participant was paid to participate in the research. Participants were reimbursed for travel and time/other associated costs at the rate of 5,000 TSh (~£2) or 10,000 TSh (~£4) per day as appropriate. I put data systems in place to ensure that information gathered from participants remained secure and confidential, such as using unique identifiers on all field notes and storing personally identifiable information on a separate password-protected database accessible only to myself.

During the course of fieldwork I found that the ethics procedures described above were not always adequate for the settings in which research was being conducted. This theme is explored further by myself and colleagues in (Ladbury *et al.*, 2017).

2.8 Reflections on the data generated

2.8.1 Positionality

“Positionality” is a term used in social sciences research to reflect on how important aspects of a researcher’s personal characteristics – such as age, gender, race, education status, country of origin, or class – relate to the research participant and the research settings; how these characteristics might affect and impact on the relationship he/she creates with their research participants; and how this may influence the nature of the data collected

(Valentine, 2005). In biomedical, quantitative research, these effects are not usually considered, much less highlighted. In this research paradigm, strict procedures of standardisation endeavour to remove the influence of the researcher from the data collected – attempting to minimise the introduction of "interviewer bias" by training research assistants to ask standard questionnaire items in exactly the same way. However, it is implausible that interviewer bias can ever be eliminated completely, given that people tend to respond to different people in different ways. In social science, it is well recognised that no two researchers would ever – or could ever - collect the same data from any one respondent, precisely because the way the respondent *responds* to each different researcher will inevitably vary. Moreover, the positionality of the researcher will also affect how s/he *interprets* the data collected. Thus the knowledge that research produces is a product of the context of the research process, a context which is always and inevitably shaped by broad and multi-level factors, at once inter-personal, social, historical and geo-political (Sultana, 2007).

My identity as a white, Western ("*mzungu*"), highly educated young woman shaped the interactions that I had with participants throughout the research process. These qualities could be both facilitative and restrictive. For example, there still remains a perception that an *mzungu* carries authority. This was something that I found personally uncomfortable, and had the potential to hamper efforts to gain a "true" characterisation of dairy trade and consumption in the area. I was frequently perceived as an expert or inspector, and the underlying unequal power dynamic would almost certainly have led to participants formulating their responses or adapting their actions and behaviour to match their expectation of what I *should* or *would want* to hear. In addition, my skin colour rendered me a conspicuous outsider, so casual observation of dairy trade activities (e.g. at the market or a milk trading point) was impossible – my presence was always an "event" that would draw people's attention and potentially change their usual behaviour. At the same time, being an *mzungu* undoubtedly had practical advantages – for example, I typically would receive research permissions from local government offices within an hour or two of first presenting at the office, whereas Tanzanian researchers from KCMC reported it would usually take them several days. The fact that I was often perceived as exotic or authoritative may also have influenced people to participate in the research; although I did worry that the latter perception represented a kind of coercion. It should not be assumed that the researcher is always in a dominant position of power, however (Valentine, 2005). In my interactions during key informant interviews at the higher levels of government office, particularly with those who had the ability to refuse me permission to conduct research in their area, I was acutely aware that the interviewees had the upper hand in terms of how the interview proceeded and how and what information was divulged and controlled.

My gender and youth generally worked to my advantage in disrupting power dynamics between myself and the research participants, perhaps particularly because the dairy industry involved so many women. I would often talk about my recent wedding and missing my new husband as a way to break the ice with the women I interviewed, and this placing of myself in a position of vulnerability helped to subvert my "superiority" as they offered tips for a successful marriage and good wishes for me to have children. My youth and foreign-ness also allowed me to feign ignorance and ask "stupid" questions in an innocent way - questions which might otherwise have been perceived as accusatory or offensive if asked directly by a compatriot (for example: "But I don't understand – why do you boil milk before drinking it to prevent disease, but you're happy to drink *mtindi* made from raw milk?").

The positionality of my research assistants is also important to consider (Turner, 2010; McLennan, Storey and Leslie, 2014). This aspect is often overlooked despite the fact that it would be impossible to generate data in the absence of effective relationships between the researcher-research assistant-research participant triad (Turner, 2010). For example, Matayo Melubo, my primary research assistant, was a young, university-educated male from the Maasai tribe. The majority of participants we worked with were Chagga women with a low level of education. Thus it cannot be assumed that power dynamics were not also at play in these relationships, simply because both research assistant and research participant were Tanzanian. Matayo's positionality would also have shaped the data we collected in aspects not solely related to power, however. For example, the Maasai are known to be frequent consumers of raw milk. If participants were simply aware of Matayo's tribe (of which there were indicators from his physical appearance), this in itself may have led to them answering questions related to raw milk consumption differently.

2.8.2 Working in a second language

Tanzania is a multi-lingual country with over a hundred languages (Ethnologue, 2017). The lingua franca are English and Kiswahili; Kiswahili is widely spoken while English is used for more official purposes. There are also many native tribal languages. In Kilimanjaro, the main tribe is the Chagga. The Kichagga language was most commonly spoken as the mother tongue in the rural areas we worked in, with Kiswahili as a second language. In Moshi Municipality, Kiswahili was more common as the mother tongue.

I designed all study materials (e.g. information sheets, consent forms, interview schedules, and questionnaires) in English, which Matayo then translated into Kiswahili. Neyeyo then back-translated these verbally into English to check for accuracy. All group discussions and proportional piling exercises were conducted entirely in Kiswahili. Key informant interviews, in-depth interviews with consumers, and questionnaires were conducted in English or Kiswahili as the respondents preferred, apart from one consumer survey questionnaire which Matayo administered in Maa (his own native language), translating the questions ad-hoc. In practice, the vast majority of respondents opted for Kiswahili. During interviews in Kiswahili, Matayo would interpret "live" – i.e. I would ask a question, Matayo would translate it, the respondent would answer and Matayo would then translate the answer back to me. This approach meant that I had control to direct themes and topics and to follow up on points that I found interesting or important, but had the disadvantage that the flow of conversation continually had to be halted in order to allow time for interpretation.

I undertook Kiswahili classes and self-study both in Tanzania and the UK from my first year of study to the time I completed fieldwork. Through this I achieved a working knowledge of the language, which brought with it various benefits such as allowing me to facilitate closer, more trusting interactions with research participants and to develop more nuanced experiences and cross-cultural understandings of the context in which I was working (Veeck, 2001; McLennan, Storey and Leslie, 2014; Watson, 2015). However, I was nowhere near fluency, as can be expected for most field researchers unless they spend many years in the field (Veeck, 2001; Bujra, 2006). Thus, I was highly dependent on my research assistants to generate the data needed for the research. This highlighted several challenges related to working in a second language, many of which were difficult to overcome:

- **Lost in translation**

English and Kiswahili have different origins and therefore often do not translate well from one to another. For example, one simple question that I asked of most respondents was "*How do you know that the milk that you buy is of good quality?*" In asking this question, I wanted to ascertain which factors my respondents considered as inherent in a good quality dairy product – taste? colour? safety? price? packaging? However, in Kiswahili there is no corresponding word/concept for "*good quality*", so this was usually translated as "*salama*". "*Salama*" in Kiswahili has a variety of meanings: "good", satisfactory", "favourable", "peace"; it can also mean "safe". Therefore, in even phrasing the question this way, connotations of safety were raised in Kiswahili that would not have been raised in English. As I used transcripts that were entirely translated into English for the analysis, this nuance was masked, though I endeavoured to be mindful of it throughout. However, it is difficult to know on how many other occasions this type of translational issue may have arisen, as my Kiswahili was simply not up to the level to pick up on more than a few such subtleties.

Conducting interviews in translation also reduced the amount of time available to interview the participants. We could only really ask for an hour of people's time maximum, and a lot of that time was spent with Matayo relaying my questions to the respondent or with him relaying the respondent's answers to me. However, despite this, I often preferred interviewing in Kiswahili to English. The use of English carries some status in Tanzania as denoting a high level of education. Therefore, some respondents, particularly key informants, preferred to speak in English as demonstrative of their education. However, this could result in a loss of depth in respondents' answers, who often had noticeable difficulties in expressing what they wished to say.

- **Added and lost in interpretation**

In addition to the issue that *translation* poses, the process of *interpretation* poses a related but separate issue. For example, during in-depth interviews with consumers, Matayo would interpret, and Neyeyo would transcribe the recorded interviews quasi-verbatim[3] into Kiswahili and then English. I would then supplement these transcripts by listening back to the audio tapes and inspecting my field notes. Having learned some Kiswahili, I was able to cross-reference the written Kiswahili and English transcripts with the audio-tapes and field notes and compare the content. Playing back the tapes, I found that on a few occasions, information had been left out of the transcripts that I would myself had considered as relevant to the research questions. On other occasions, Matayo had provided a layer of additional interpretation to a respondent's answer which had not actually been directly communicated by the respondent. These examples highlighted that the process of interpretation – both of a respondent's words and of a researcher's objectives– is itself subjective, and information can be both spuriously added, or inappropriately left out.

For logistical reasons, during the second phase of fieldwork I wrote up all the interactions with research participants directly into English myself using my written notes rather than employing a research assistant to type up Kiswahili and English transcripts. However, it was clear from the earlier fieldwork that in so doing, I could not be sure that the material I eventually collected was a literal, or even near-literal, representation of the study participants' own words, void of any interpretation or analysis conducted "between" me and them. To address this, I periodically went through a particular transcript while Matayo translated the related audio-tape verbatim, so that I could ascertain to what degree information may have been added or lost. This activity provided continued training to Matayo regarding interpretation for the research; however, it is inevitable that when working in a second language, all information generated is itself shaped by the process of interpretation. The nature of this shaping depends not just on the research assistant's level of language fluency or

[3] Strict verbatim transcription is very labour intensive and time consuming (and therefore costly). For these reasons, I judged that as long as transcripts gave the essence of people's statements and were thus a fair representation of what was said, this was sufficient. However, deciding what represents the "essence" of what someone has said is of course itself a subjective process.

understanding of the research objectives, but also on myriad, shifting factors such as the assistant's positionality in relation to the research participant and researcher, their mood on the day of research, and so on (Bujra, 2006; McLennan, Storey and Leslie, 2014; Watson, 2015).

- **Lost outside translation**

Not being fluent in Kiswahili also meant that I did not have access to a lot of background information I could otherwise have picked up during participant observation, such as by overhearing snippets of conversation between traders and customers. In some cases Matayo would relay these to me if he thought they were relevant, but in rural areas we were often doubly disadvantaged as much on the incident conversational exchanges were held in Kichagga,which Matayo did not understand. Indeed, it is possible that the fact that we could not communicate in Kichagga restricted the voices that were in the research. As Watson (2015) notes, working solely in a lingua franca such as Kiswahili has the potential to exclude people such as women and more marginalised groups, who may not have had the opportunity to have benefitted from learning these languages. It is possible, for example, that older, poorer women in rural villages would not have had a sufficient level of Kiswahili to participate in the research. Their voices would have been lost to us, which is of concern given that fieldwork demonstrated that value chain participation in rural areas was dominated by women, and was often a strategy to increase income in poorer households.

In summary, working in a second language added a layer of complexity to the research, especially with regards the qualitative elements which were heavily based on listening to what people *say* and extrapolating from this to interpret *meaning*. It is incontestable that my not being able to fully understand nor fluently converse in the Kiswahili language – or at all in the Kichagga language - had a large impact on both the amount and quality of the data I managed to collect, and the relationship that I have with those data.

2.9 Value chains as heuristic devices versus value chains as analytical tools

In their *Handbook for Value Chain Research*, Kaplinsky & Morris (2000, p24) state that value chains can be used either as heuristic devices ("*allowing for a better* *description of the world*") or as analytical tools ("*explaining* why *the world takes the form it does*"). The authors argue that as a heuristic device, a value chain provides a detailed descriptive construct characterising how a product comes into being, with all the steps, actors and activities that involves, and that this in itself can be valuable information. However, at as an analytical tool, they argue that value chains can generate wider insights into, for example, determinants of global income distribution or what policy measures might be effective in reducing inequalities.

As discussed in Section 2.2, standardised methods of FBD risk assessment have not commonly been applied to food value chains in developing countries in large part because their messy complexity has precluded the application of systematic methods to evaluate risk. In this thesis, I have sought to overcome this by attempting to disentangle this complexity through describing the existing dairy value chains in a simplified form, from which specific risk pathways could be mapped and qualitative risk pathway analysis undertaken. In Chapter 3, which is concerned with the patterns of dairy consumption and acquisition in Moshi Municipality, I describe how residents were found to be consuming two main dairy products: unpackaged milk and fermented milk (*mtindi*). Chapters 4 and 5, which are concerned respectively with the structure and function of the dairy value chain serving the town, demonstrate how multiple linked actors, activities and geographies are involved in supplying these two products to the town. In order to reduce this complexity and develop a robust framework from which a risk assessment could be applied, through most of the thesis (Chapters 4 – 6), I present these two products (milk and *mtindi*) as having two separate value chains, each with a largely linear form. Within each chain, I consider two separate strands – a rural-to-urban strand and an urban-to-urban strand - defined by where the end-product (i.e. milk or *mtindi*) is produced. In the rural-to-urban strand, the end-product is produced in the rural surrounds of Moshi Municipality and brought into the town for sale. In the urban-to-urban strand, the end-product is produced in the town itself, i.e. for milk, the cow is located and milked in town, and for *mtindi,* the fermentation process occurs within the town (although the milk that is used for this process may have originated in rural areas).

In this mode of characterising the dairy value chain as separated, simplified, linear entities, I am following Kaplinsky & Morris' (2000, p24) idea of value chains as heuristic devices, affording a "*better description of the world*"; serving to indicate the various points and processes of a chain; the actors, activities and geographies involved; and condensing this information to provide the type of framework that is necessary for the systematic evaluation of assorted data that is intrinsic to qualitative risk assessment. However, while facilitating evaluation and understanding on one level, the inevitable consequence of simplification is that the overall complexity of the dairy value chain is lost. The accompanying danger is that this loss of the sense of the "whole" may obscure the wider implications and overall messages that can emerge from interrogating the entire picture, with all its inherent conflicts and intricacies. Thus, in Chapter 7 I shift focus and "zoom out" to again consider the dairy value chain serving Moshi Municipality as one entity, where milk and *mtindi* are just two of any number of dairy products that might be sold and consumed within the town. In this final chapter, I draw on the data and insights generated in previous chapters to use the value chain as an analytical tool to examine the wider implications of the research findings in terms of current and future livestock and food safety policy in Tanzania, as well as the strengths and limitations of using value chain approaches to assess FBD risk.

3 Patterns of dairy consumption and acquisition in Moshi Municipality

3.1 Summary

In order to investigate patterns of dairy product consumption and acquisition by residents of Moshi Municipality, we conducted fieldwork in ten randomly selected wards and an eleventh purposively selected pilot ward. We generated quantitative and qualitative data through nine key informant interviews with ward/district-level government officials from the eleven wards, group discussions and proportional piling exercises (eight wards and seven wards respectively), a randomised survey of 151 households across the ten selected wards, and twelve in-depth interviews with thirteen respondents to this survey. Our results found that the most frequently consumed product was boiled unpackaged milk, with over 60% of survey respondents consuming it at least weekly, followed by *mtindi* (fermented milk) which 44% respondents consumed at least weekly. Western-style products such as pasteurised milk, cheese, butter and cream were infrequently consumed. The lack of appetite for pasteurised and processed products did not reflect a lack of interest in health concerns or food safety. Consumers were highly motivated by health considerations and used these to inform a range of dairy food choices such as what products to include in the diet or where to acquire them from. There was a strong preference for boiling milk before consumption; however the majority of consumers did not know whether the *mtindi* they consumed was made from boiled or raw milk, suggesting a possible food safety risk. Notably, children, mothers of newborn babies, the sick and the elderly were each identified as population groups that consumed increased amounts of milk or *mtindi* compared to the general population; these groups are also potentially more vulnerable to food borne diseases owing to their reduced immunity.

3.2 Introduction

There is widespread agreement that urbanisation drives changes in the human diet, owing to changes in food affordability, availability, desirability and convenience (Herforth and Ahmed, 2015). However, to date these changes have been identified primarily at the macro-level, by observing changes in the quantities of food groups produced, purchased or sold (Popkin, 1998; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). There are very few empirical data on the structure of diets in urban and urbanising centres at the individual or household level, nor on food acquisition practices nor the factors that drive the individual dietary choices of urban residents (Global Panel on Agriculture and Food Systems for Nutrition, 2016a). The lack of detailed data on urban food consumption and acquisition patterns is a major barrier to investigating FBD risks faced by urban residents in developing countries, and impedes the formulation of evidence-based research and policy surrounding changing food systems and urban health. In light of this, the Global Panel on Agriculture and Food Systems and Nutrition (2016b) has asserted that the collection of empirical urban dietary data is an urgent global research priority.

The process of urbanisation has led to a "nutrition transition" in both developed and developing countries, a feature of which is urban residents consuming a larger proportion of animal source products (ASPs) in their diets compared to their rural counterparts (Popkin, 1994; Neumann, CG *et al.*, 2010; Steyn and Mchiza, 2014). A common assumption of nutrition transition theory is that urbanisation drives demand for Western-style foodstuffs in response to an environment where advertising is more pervasive, food outlets more numerous, and where residents may have more disposable income, as such food items are regarded as desirable and increasing social status (Steyn and Mchiza, 2014). Following this assumption, it could be expected that urbanisation in East Africa would lead to an inexorable rise in the consumption of pasteurised and processed dairy products. However, several studies have suggested a more nuanced picture. Studies from Kenya comparing dairy consumption patterns in rural and urban areas have found that urban pasteurised product consumption does indeed exceed that of rural areas (Omore *et al.*, 2000; Njarui *et al.*, 2011); however, these and other studies have found that the amount of pasteurised dairy products included in the East African urban diet remains small (Melesse and Beyene, 2009; Njarui *et al.*, 2011; Akaichi, Chalmers and Revoredo-Giha, 2016; Haesler, Msalya, Garza, Fornace, Eltholth, Kurwijila, *et al.*, 2017). Current evidence from across the region suggests that, even in urban areas, there is a widespread preference for boiling raw or unpackaged milk rather than pasteurised, packaged dairy products (Haesler et al. 2016; Njarui et al. 2011).

Similar preferences were found in an earlier study from Kenya comparing rural and urban diets, suggesting that these preferences may be relatively stable (Omore *et al.*, 2000). Fermented milk is another traditional dairy product that is favoured in several African countries. Surveys from both Kenya and Ethiopia have shown that in both rural and urban areas, fermented milk products are one of the most consumed dairy products after milk itself in terms of either frequency or quantity of consumption (Haesler et al. 2017a and b; Njarui et al. 2011; Melesse & Beyene 2009; Omore et al. 2002), while studies from Zambia and Kenya which focus on plain milk also mention the popularity of fermented milk as an aside (Omore, Arimi and Kang'ethe, 2002; Knight-Jones *et al.*, 2016).

The studies above highlight the need for more empirical data on dietary composition and for more detailed contextual analysis of the factors that govern diet choice, rather than relying on the assumption that the character of the nutrition transition will inevitably follow a Western model. It does not necessarily follow that the increased inclusion of ASPs in urban diets in developing country diets will mean increased inclusion of “modern” Westernised ASPs. This chapter investigates the patterns of dairy product consumption in Moshi Municipality, providing empirical data on what dairy products residents of this urban area choose to include in their diets, where they acquire them from, and the determining factors and rationale which lie behind these decisions.

3.3 Methods

We used a range of methods to investigate dairy consumption within Moshi Municipality, each of which explored the following themes:

- Household dairy consumption patterns and practices
- Household acquisition and purchasing patterns and practices
- Knowledge, perceptions and practices regarding the health risks/benefits of consuming dairy products
- Knowledge of the dairy value chains supplying Moshi Municipality

Fieldwork was conducted in the ten wards randomly selected for the household survey (see section 3.3.2), plus an eleventh purposively selected ward in which quantitative field materials were piloted in addition to qualitative data proper being collected (see Figure 2-5 for a map of study wards).

3.3.1 Key informant interviews

We conducted nine[4] key informant interviews with relevant ward-level officials (e.g. ward executive officers, livestock field officers, and health officers) from all of the wards in which we were working, as well as with dairy representatives at Moshi Municipality district office and with the Chair of the National Dairy Board (Appendix 2). Study materials (e.g. consumer survey questionnaire, interview schedules, etc) can be found in Appendix 3.

3.3.2 Household consumer survey

We conducted a randomised household consumer survey within Moshi Municipality in order to gather data from a representative sample of the population. The method meant that quantitative estimates regarding dairy product consumption and acquisition could be calculated from the sample and extrapolated to the district level.

I defined the study population as all households of the wards belonging to the district of Moshi Municipality, as described in the 2012 Tanzania census (Tanzanian National Bureau of Statistics, 2013). Defining what comprises a "household" in sub Saharan Africa is complex and can depend on a range of cultural and context-specific factors (Coast, Randall and Leone, 2009; Randall, Coast and Leone, 2011). To allow comparison with other studies, I employed a standard definition that was being used in other epidemiological research in the Kilimanjaro region (Cash-Goldwasser et al. In Press). This defined a household as the group of people currently living in the same compound and sharing the same kitchen, where a compound is the bounded area/space directly around a dwelling (which may include other households).

- **Study design**

The survey sample was selected using a two stage cluster design. Such a study design is useful when there is no list of households to use as a sampling frame

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[4] Two KIIs involved representatives from more than one ward

from which households can be randomly selected, and simple random sampling would be impractical. This sort of study design is discussed in detail in Bennett *et al.* (1991).

The two stages involved in this survey were thus: firstly, I randomly selected the wards within Moshi Municipality district in which the study would take place, and secondly, I randomly selected clusters of households within those wards.

Selection of wards in the first stage was done with probability proportional to ward population size according to the 2012 census (Tanzanian National Bureau of Statistics, 2013). This ensured that each household had an equal probability of selection, i.e. a household in a populated ward had an equal chance of being selected as did a household in a less populated ward. In theory, sampling with probability proportional to size could lead to a highly populated ward being selected more than once, in which case the corresponding number of clusters of households would be randomly selected within that ward. However, in our study no ward was selected more than once. Having selected the wards in which the clusters would be located, the second stage was to randomly select the households in those wards that would make up a cluster. The methods I used to do so will be discussed in detail below, under the bullet point entitled "Sampling".

Using a cluster study design has statistical implications. Firstly, clustering introduces an extra degree of variance into the sample compared to if the sample had been selected through simple random samples, as there is variance *within* clusters and variance *between* clusters. The degree of extra variance is quantified as the "design effect".

$$\text{Design effect (deff)} = \frac{\text{actual variance in the sample}}{\text{expected variance if using simple random sampling}}$$

Design effect must be taken into account when calculating sample size, i.e. clustered surveys require a sample size that is equal to the sample that would be required by simple random sampling, multiplied by deff. However, paradoxically, it is impossible to predict what deff will be until the sample has been taken; thus, it is common to use a figure for deff that has been found in similarly designed studies performed in the region.

Secondly, clustering affects the precision of estimates, typically widening confidence intervals. Precision can be increased by having a higher number of smaller clusters (e.g. for a required sample of, say, 100 households, a sample of 20 clusters of five households would yield more precise estimates compared to five clusters of 20 households). However, there is a trade-off between recruiting a larger number of clusters and the increased workload involved, and the associated increases in costs and time.

The clustered design of a survey must therefore be taken into account during analysis, and estimates of means and proportions etc adjusted accordingly. Statistical software packages specifically designed for survey data are able to assist with this.

- **Sampling**

Sample size calculations suggested a required sample of 145 households to allow the main outcome variables (proportions of households consuming a certain product) to be estimated with 10% precision and 95% confidence assuming a prevalence of 50% (World Health Organization, 2015) and deff of 1.5 (based on previous cluster design surveys carried out in Moshi Municipality and mainland urban/northern Tanzania (Tanzania National Bureau of Statistics and ICF Macro, 2011; Tanzania Commission for AIDS *et al.*, 2013; Ostermann *et al.*, 2014)). Given the time and resources available to us in the field, I determined that the maximum number of clusters we would be able to recruit would be ten.

The first stage of sampling required that I select ten cluster locations from the twenty-one wards belonging to Moshi Municipality using probability proportional to size of the 2012 ward population (Tanzanian National Bureau of Statistics, 2013). I carried this out using the method described by Bennet el al (1991) , i.e. by creating a cumulative list of ward population sizes (Table 3-1), and dividing the total population of the district (184,292) by the number of clusters to be selected (ten) to obtain a sampling interval of 18,429.

Figure 3-1 Schematic representation of two stage cluster sampling in fictional District X

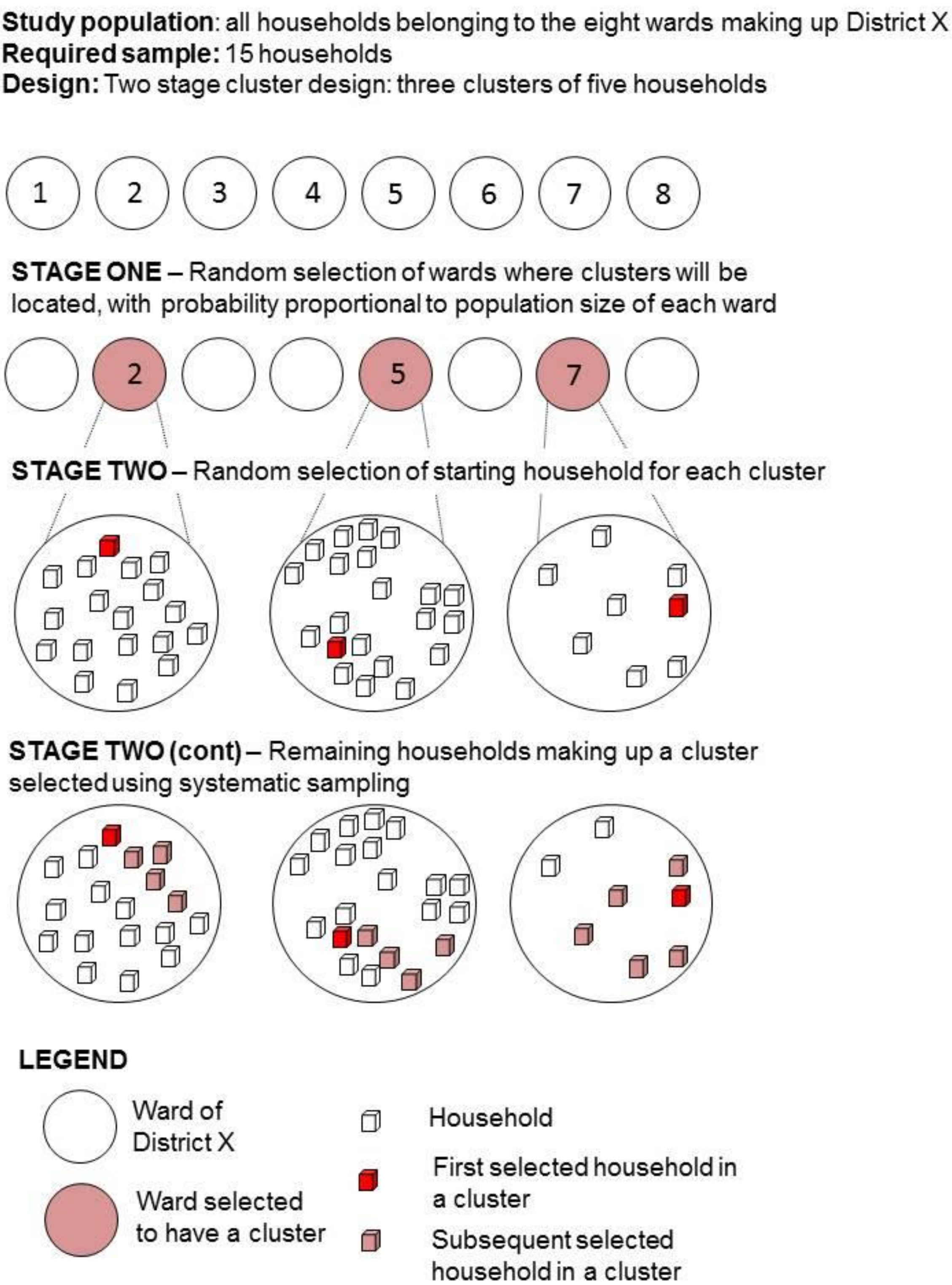


Table 3-1 Random selection of household clusters for consumer survey in Moshi Municipality using probability proportional to ward population size

Ward	Total population (2012 census)	Cumulative population	Cumulative sampling interval	Cluster number
Boma Mbuzi	15,776	15,776	1547	1
Bondeni	4,050	19,826		
Kaloleni	6,554	26,380	19,976	2
Karanga	7,124	33,504		
Kiboriloni	9,206	42,710	38405.4	3
Kilimanjaro	5,233	47,943		
Kiusa	5,950	53,893		
Korongoni	5,815	59,708	56834.6	4
Longuo B	6,632	66,340		
Majengo	9,006	75,346	75263.8	5
Mawenzi	1,770	77,116		
Mfumuni (Ngangamfumuni)	4,750	81,866		
Miembeni	15,220	97,086	93693	6
Mji Mpya	15,293	112,379	112122.2	7
Msaranga	7,699	120,078		
Ng'ambo	7,890	127,968		
Njoro	14,296	142,264	130551.4	8
Pasua	13,460	155,724	148980.6	9
Rau	9,137	164,861		
Shirimatunda	4,485	169,346	167409.8	10
Soweto	14,946	184,292		
Total	**184,292**			

I then selected a random number between 1 and 18,429 as a start point (1547). As this number lay between 1 and 15,776, the first ward selected for a cluster was Boma Mbuzi. I then added the sampling interval (18,429) to the initial random number (1547), equalling 19,976. As this number lay between 19,826 and 26,380, Kaloleni was selected as the second ward for a cluster. I continued this process of systematic sampling until all ten clusters were identified (highlighted in yellow in Table 3-1). As no ward had a population greater than the sampling interval, each cluster was situated in a different ward, i.e. ten wards were selected.

The next stage was to select a cluster of households within each selected ward. I randomly selected starting households for each cluster within each ward by using GIS software to generate five random points (#1-#5) within that ward (QGIS

Development Team, 2013-2015). Using Google Maps satellite imagery, I selected the nearest roof to random point #1 as the starting household in a cluster. In the case that a point fell within an uninhabited area (defined as no roof visible within a 250m radius of the random point), I substituted the randomly generated points in sequence until a roof was identified. If once in the field we found that the first selected roof was a compound containing several households, we counted the total number of households in that compound, and then selected one household at random to be the starting household using a random number smartphone application (Muse Guy Productions, 2013). If we found that the first selected roof was a building other than a household, we selected the nearest household to the left (when standing with our backs to the main entrance to the building) as a starting point.

Having identified the starting household, we used systematic sampling (every third household to the left, when standing with our backs to the main entrance of a household) to recruit the remaining households for a cluster. In the case of non-response (i.e. absence), non-inhabitation, household refusal to participate, or ineligibility to participate, the next nearest household to the left was selected as a replacement where possible. Where not possible (e.g. the neighbouring household was also absent), replacements were made by continuing to systematically select extra households at the end of the cluster. At least three visits were made to a selected household before it was deemed as absent/not inhabited. These three visits were made at different times of the day/week in order to avoid biasing the sample e.g. by excluding people who were working.

One respondent per household was purposively selected to participate in the survey on behalf of the whole household. Where possible, the female head of household was preferentially invited to participate on the assumption that she would have the best overview of the household’s food acquisition and consumption habits. If she was not available, the male head of household was the second choice. If neither were available, any other household member willing to participate was recruited to the study. Individuals who had been resident in the area for less than 6 months or were under 18 years of age were ineligible to participate.

- **Data collection**

Data were collected by face to face interview using standard paper questionnaires (see Appendix 3). The questionnaire consisted of four main sections. The first section collected demographic information such as age, tribe, household composition, and length of residence in the household. The second section was concerned with frequency of consumption of various dairy products by the household in general, in the previous week, and at different times of the year. It also collected information on place of acquisition of the dairy products reported as being consumed most frequently. The third section was concerned with consumer knowledge, attitudes and practices with regard to the health and safety aspects of including dairy products in the diet. The forth section collected information on household assets with a view to using these data to create a socio-economic status index (Filmer and Pritchett, 2001; Vyas and Kumaranayake, 2006; Krefis *et al.*, 2010). This section also collected indicators of food security as detailed by the Food and Nutrition Technology Assistance (FANTA) Household Hunger Scale (HHS), a household food deprivation scale specifically developed and validated for cross-cultural use (Deitchler *et al.*, 2010; Ballard *et al.*, 2011). In the final section, participants were asked to name any value chain contacts they had. We conducted a small pilot study over two days in Longuo ward and updated the survey procedures and questionnaire accordingly prior to commencing the survey proper. The survey was conducted over a period of six weeks from November-December 2013.

3.3.3 In-depth interviews

We conducted twelve semi-structured in-depth interviews with thirteen respondents (Appendix 2) who were identified in the consumer survey and who had agreed to the prospect of a follow-up interview (in one interview, two respondents were interviewed together). The interviewees were purposively selected based on their responses to the survey (e.g. dairy products they reported consuming, or the vendors they reported acquiring them from) in order to ensure that we heard a range of views and opinions regarding dairy product consumption and acquisition practices.

3.3.4 Group discussions

We conducted semi-structured group discussions with community members from eight of the selected study wards (Appendix 2). The groups were convened by ward officials, either by engaging existing community groups (e.g. business co-operatives) to participate or by convening an ad-hoc group for the purpose according to the ward official's preference. My research assistants Matayo Melubo and Neyeyo Lucumay ran the discussions, each of which were held at the ward office and lasted about two hours. Matayo facilitated while Neyeyo took detailed written notes (e.g. composition of the group, which participant spoke when, comments on late arrivals/early leavers and group dynamics). I attended the first two sessions to oversee the activities and ensure that the planned protocols were running smoothly; however, to ensure smooth flow of dialogue I did not ask for interpretation during these sessions. In order to avoid the potential influence that my presence might have on the frankness of discussions, I did not attend the remaining six sessions. Matayo, Neyeyo and I would meet to debrief immediately after they had returned from the field in order to keep me abreast of the emerging findings.

3.3.5 Proportional piling

Six of the eight consumer group discussion sessions described above commenced with two proportional piling exercises, which acted as an icebreaker as well as a way to generate semi-quantitative data on dairy consumption and acquisition patterns within the community. In the first exercise, participants were asked to brainstorm about the different dairy products their household members consumed, and then to allocate a pile of 50 beans to a matrix denoting those products by cow, sheep or goat origin, according to the proportions consumed. In the second exercise, participants were asked to brainstorm the different places they may acquire those products. They were then asked to proportionately allocate 50 beans to a matrix denoting the top five most commonly consumed products identified in the first exercise by place of acquisition.

3.3.6 Analysis

I analysed the consumer survey data in Stata IC14 (StataCorp, 2015) using Stata survey "svy" commands and weighting by cluster size so that estimated proportions were adjusted for the cluster sampling design (StataCorp, 2013). I generated a proxy variable for socio-economic status (SES) by performing principal components analysis using data on households assets, following the method described by Vyas & Kumaranayake (2006) in their methodological paper on how to construct SES indices using asset data collected in developing country contexts. I generated a food security variable using information from the HHS as described by Food and Nutrition Technical Assistance (FANTA) (Ballard *et al.*, 2011). I performed descriptive analysis to describe the study population in terms of demographics, dairy consumption and acquisition practices, and attitudes towards the health and safety of dairy products. I then conducted univariable analysis using ordered logistic regression to identify associations between explanatory variables such as demographic characteristics or SES and dairy product consumption outcome variables (e.g. "Consumed product X weekly/Consumed product X less than weekly/Never consumed product X"). I conducted multivariable analyses using ordered logistic regression to investigate explanatory variables associated with frequency of consumption ("Weekly/Less than weekly/Never") of boiled milk and of *mtindi* (fermented milk). For these models, I entered all explanatory variables where $p < 0.2$ in univariable analysis, and used a process of backwards selection to remove variables one at a time depending on the outcome of significance testing ($p<0.05$) using the likelihood ratio test. I also performed binary logistic regression to explore relationships between explanatory variables and place of dairy product acquisition as outcome (e.g. "Purchases in shop -Yes/No"), and with "always buys dairy products from the same source - Yes/No" as an outcome.

I analysed the qualitative dataset (KIIs, IDIs and group discussion transcripts) using thematic analysis. As a first step, I read through each transcript whilst listening to the relevant audio-tape in order to familiarise myself with the data, amending the transcript to include additional information where necessary (see Chapter 2 Section 2.8.2, Working in a second language). I loaded finalised transcripts into NVivo10 to aid further analysis (QSR International Pty Ltd, 2012). Reading line by line, I coded the transcripts by assigning both deductive ("etic") codes (codes which I pre-decided prior to the process of analysis) and inductive ("emic") codes (codes which emerged through the process of reading through the data). As the analysis progressed, I grouped codes into emerging themes, repeating the process until I had read through the full dataset several times and no further codes or themes were identified.

I analysed the proportional piling data in Excel (Microsoft, 2010), calculating and comparing the percentage of beans placed on each square of the matrices generated during discussion.

3.4 Results and Discussion

3.4.1 Response rate and study population

A total of 252 households were approached for participation in consumer survey, of which 42 had no person present at any of the three visits; 38 were ineligible; and 21 refused to participate. This left a total of 151 participating households, equivalent to an overall response rate of 88% (Table 3-2) and in excess of the required sample size. Of the 38 ineligible households, 34 (90%) were ineligible owing to the potential respondent being resident in the household for less than six months; in the remaining four households the potential participant was under 18 years of age.

Mean household size was 4.6 residents (95% CI: 4.3 - 5.0), similar to the mean of 4.3 in Kilimanjaro found in the 2012 census, indicating that the study sample was a good representation of the overall population (Tanzanian National Bureau of Statistics, 2013). Data regarding the maximum length of time any resident had lived at the household were substantially right-skewed (Figure 3-2), reflecting the high rate of flux within the urban population. This included movement of households within Moshi Municipality as well as migration into the district from other areas; unfortunately the survey data we collected regarding previous household location were of insufficient quality to distinguish the relative proportions of migration within versus into Moshi Municipality.

Table 3-3 and Table 3-4 show the results of the principal components analysis (PCA) of asset variables. The first principal component listed in Table 3-3

(Component 1) is assumed to measure socio-economic status (SES) (Vyas and Kumaranayake, 2006) and explains 28% of the variance in the sixteen asset variables entered into the PCA. This component was used to create the SES variable, categorizing into quintiles to represent poorest, poor, middling, rich, and richest households. Table 3-4 breaks down the contribution of each of the sixteen variables to the SES score. An asset with a positive factor score is associated with a higher SES; an asset with a lower negative score is associated with a lower SES. The higher the absolute value of the factor score, the more unequally distributed the asset was between households and the greater its contribution to the combined SES score. For example, electricity made the highest contribution to the combined SES score. (Vyas and Kumaranayake, 2006)

Appendix 2 lists the participants of the group discussions and in-depth interviews, as well as some of their demographic characteristics.

Figure 3-2 Consumer household survey: maximum number of years any household occupant had resided at the property (N=151)

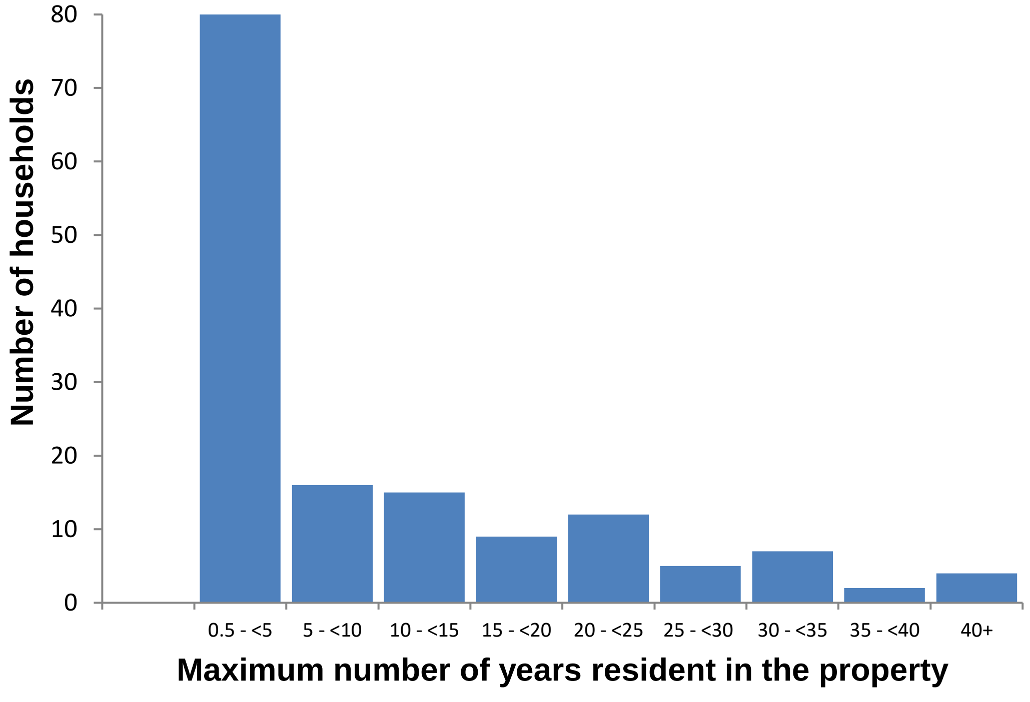


Table 3-2 Consumer survey participation and response rates by ward

Cluster number	Cluster name	Total households approached	Number of non-absent, eligible households	% non-absent, eligible households of total approached	Total consenting, non-absent eligible households	% consenting of non-absent, eligible households
1	Miembeni	25	17	68	15	88
2	Majengo	28	18	64	17	94
3	Kaloleni	27	18	67	16	89
4	Mji Mpya	23	18	78	17	94
5	Boma	19	15	79	15	100
6	Pasua	24	18	75	16	89
7	Shirimatunda	28	18	64	15	83
8	Korongoni	28	18	64	13	72
9	Njoro Moshi	30	18	60	14	77
10	Kiboriloni	20	14	70	13	93
	Totals	252	172	68	151	88

Table 3-3 Results of principal components analysis of household assets in consumer survey (N=151): components and variance explained

Component	Eigenvalue	Proportion of variance explained	Cumulative variance explained
Component 1	**4.4709**	**0.2794**	**0.2794**
Component 2	1.7557	0.1099	0.3893
Component 3	1.6648	0.1040	0.4934
Component 4	1.3106	0.0819	0.5753
Component 5	1.1953	0.0747	0.6500
Component 6	0.9694	0.0604	0.7105
Component 7	0.9233	0.0577	0.7682
Component 8	0.7346	0.0459	0.8141
Component 9	0.6730	0.0421	0.8561
Component 10	0.6053	0.0378	0.8940
Component 11	0.5364	0.0335	0.9275
Component 12	0.5149	0.0322	0.9597
Component 13	0.4379	0.0274	0.9870
Component 14	0.2072	0.0130	1.0000

Table 3-4 Results of principal components analysis - factor scores for asset variables included in the analysis

Variable description	Factor score
Electricity	0.3573
TV	0.3545
Fridge	0.2916
Flush toilet	0.2853
Cement	0.2789
Sofa	0.2769
Bank	0.2744
Tap water	0.2638
Car	0.2115
Radio	0.2003
Iron	0.164
Motorbike	0.0989
Bed net	0.0098
Bike	0.006
Earth floor	-0.2789
Pit latrine	-0.2853

3.4.2 Types of dairy products included in the diet

As found in other studies in the East African regions, our findings showed that Moshi Municipality residents consumed unpackaged, "traditional" products such as boiled or fermented milk far more frequently than more Western products such as packaged pasteurised milk or cheese (Haesler et al. 2011; Melesse & Beyene 2009; Akaichi et al. 2016; Omore et al. 2000). Table 3-5 presents the findings of the consumer survey regarding types of dairy products consumed. The results are for cows' milk products only; no participants reported consuming goat or sheep's milk products. Table 3-6 presents results from the proportional piling exercise regarding the same topic. By far the most frequently consumed product reported was boiled, unpackaged milk with over 60% of respondents consuming it weekly or more frequently, and a further 34% consuming it less than weekly. Only 5% reported never drinking boiled unpackaged milk (Figure 3-3). This finding was supported by the proportional piling results, in which unpackaged milk was reported as in the top four most consumed dairy products in all seven wards (Table 3-6 and Figure 3-5). The next most frequently consumed product reported in the consumer survey was unpackaged *mtindi* (fermented milk), which 44% and 46% of participants reported consuming at least weekly or less than weekly respectively. This again was supported by the proportional piling findings whereby *mtindi* was universally reported in the top four dairy products in all wards (Figure 3-5).

The group discussions and in-depth interviews offered the opportunity to explore how these dairy products were consumed. Participants explained that unpackaged milk could be consumed plain (particularly by children), mixed with coffee, as *chai* (milk boiled with tea), or as a key ingredient in culinary dishes. Indeed, almost a third of respondents reported drinking *chai* at least weekly, and a further 30% reported drinking it less than weekly; *chai* was cited in the top four dairy products in proportional piling in all but one ward (Table 3-5 and Table 3-6). In all group discussions and interviews, respondents reported that they always boiled milk before consumption and expected that all or almost all people living in town did the same, consistent with the results seen in the consumer survey.

Table 3-5 Frequency of consumption of dairy products as reported in consumer survey N=151 households

Product	Frequency of consumption					
	At least weekly		Less than weekly		Never	
	n	% (95% Cis)	n	% (95% Cis)	n	% (95% Cis)
Unpackaged milk						
• **Boiled**	92	60.8 (51.2 - 69.6)	51	33.9 (24.9 - 44.2)	8	5.3 (2.9 – 9.5)
• **Raw**	0	0	2	1.3 (0.3 - 5.6)	148	98.7 (94.4 - 99.7)
• **Raw milk eaten with other foods (eg porridge)**	1	0.7 (0.1 - 6.1)	1	0.6 (0.1 - 5.8)	149	98.7 (94.3 - 99.7)
Unpackaged *mtindi*						
• **Made from raw milk**	3	2.1 (0.7 - 6.5)	1	0.7 (0.1 - 6.1)	147	97.2 (90.8 - 99.2)
• **Made from boiled milk**	8	5.5 (2.3 - 12.3)	4	2.5 (0.7 - 8.3)	136	92.1 (82.1 - 96.7)
• **Not sure if made from raw or boiled milk**	56	37.5 (29.9 - 45.8)	65	43.7 (36.8 - 50.8)	28	18.8 (11.2 - 29.8)
• **Any kind of unpackaged *mtindi***	66	43.7 (36.3 - 51.3)	69	45.5 (40.0 - 51.1)	16	10.9 (6.0 - 18.9)
Chai (milky tea)	50	32.8 (25.7 - 40.9)	46	30.9 (21.8 - 41.7)	53	36.2 (24.7 - 49.6)
Packaged milk	7	11.2 (5.3 - 22.1)	17	4.8 (1.5 - 14.4)	127	84.0 (68.0 - 92.8)
Packaged *mtindi*	5	3.4 (1.0 - 11.1)	19	12.3 (5.7 - 25.6)	127	84.3 (72.0 - 91.9)
Packaged cream, cheese or butter	2	1.4 (0.3 - 6.1)	28	19.4 (11.2 - 31.5)	119	79.2 (65.6 - 88.4)
Raw milk products						
• **Cheese**	0	0	1	0.6 (0.1 - 5.8)	150	99.4 (94.2 - 99.9)
• **Butter**	1	0.6 (0.1 - 5.8)	2	1.3 (0.3 - 5.5)	148	98.1 (94.2 - 99.4)
• **Cream**	0	0	0	0	151	100
• **Other**	0	0	0	0	151	100
Cheese/butter/other dairy product but not sure if raw or boiled/pasteurised	3	1.8 (0.4 - 8.6)	9	5.6 (1.9 - 15.4)	139	92.6 (78.2 - 97.8)

Table 3-6 Results of proportional piling exercise investigating the type of dairy products consumed by community members and relative frequency of consumption[5]

Ward	Products elicited	Cow		Goat	
		Number of beans	Percentage of beans	Number of beans	Percentage of beans
Boma Mbuzi	*Mtindi*	8	33	0	0
	Unpackaged milk	7	29	0	0
	Chai	6	25	0	0
	Butter	3	13	0	0
Kiboriloni	Unpackaged milk	15	38	0	0
	Mtindi	14	35	0	0
	Butter	6	15	0	0
	Chai	4	10	0	0
	Yoghourt	1	3	0	0
Korongoni	*Mtindi*	8	29	0	0
	Chai	7	25	1	4
	Unpackaged milk	7	25	0	0
	Butter	4	14	0	0
	Cheese	1	4	0	0
Longuo	Unpackaged milk	16	41	0	0
	Milk with other foodstuffs	11	28	0	0
	Mtindi	6	15	0	0
	Chai	6	15	0	0
Majengo	Unpackaged milk	8	21	2	5
	Mtindi	7	18	1	3
	Milk with other foodstuffs	6	16	1	3
	Chai	5	13	0	0
	Ice cream	5	13	0	0
	Butter	3	8	0	0
	Cheese	0	0	0	0
Mji Mpya	Milk with other foodstuffs	8	30	0	0
	Mtindi	6	22	0	0
	Ice cream	4	15	0	0
	Unpackaged milk	3	11	0	0
	Butter	3	11	0	0
	Chai	3	11	0	0
	Cheese	0	0	0	0
Njoro Moshi	Milk with other foodstuffs	12	24	4	8
	Chai	9	18	1	2
	Unpackaged milk	8	16	1	2
	Mtindi	7	14	1	2
	Ice cream	4	8	0	2
	Butter	2	4	1	2

[5] Note that where participants listed a foodstuff that is made by mixing with a dairy product, rather than being a dairy product per se, this is presented here as the aggregate "milk with other foodstuffs". Foods represented in this way include: *loshoro* (a Maasai dish made of *mtindi* mixed with ground maize flour porridge); *mlaso* (*mtindi* mixed with blood; *kitalolo* (a Chagga dish made of *mtindi* mixed with bananas and either green vegetables or maize flour); and *uji* (a liquid porridge made from maize meal, into which milk may be mixed either during or immediately after cooking). The exception to the rule is *chai* (hot spiced milky tea); this is included in its own category as it had such a high representation in each group.

Figure 3-3 Consumer survey results showing frequency of consumption of different types of milk (N=151 households)

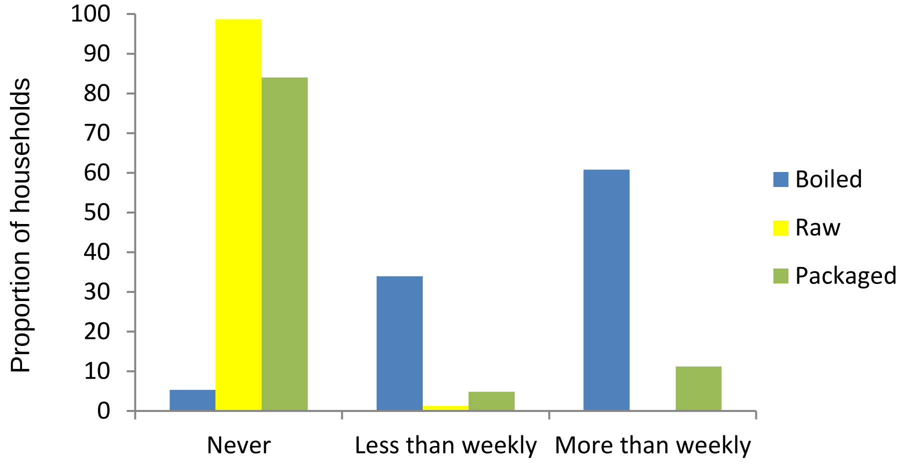


Figure 3-4 Consumer survey results showing frequency of consumption of different types of mtindi (N=151)

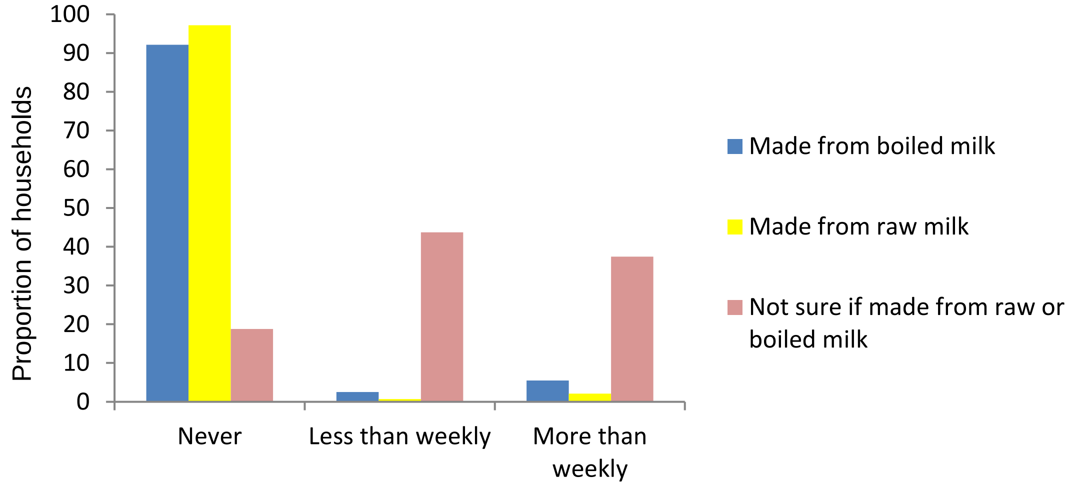
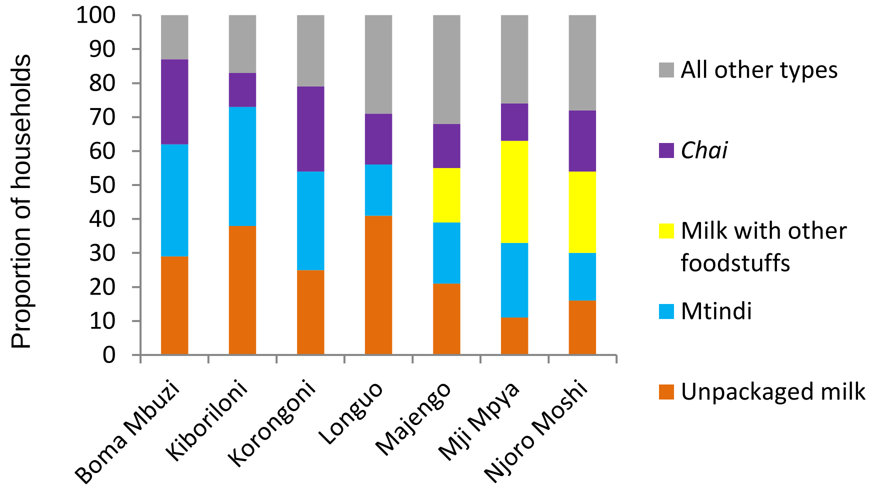


Figure 3-5 Results of proportional piling exercise regarding what dairy products participants' households most frequently consumed



Mtindi was consumed as purchased with no additional preparation stage – unlike liquid milk, it is not possible to boil *mtindi* before consumption. *Mtindi* could be consumed either as a cold drink, as a side dish for other foods such as *ugali* (a dough made from maize flour), or as an ingredient for other dishes (the use of milk and *mtindi* to prepare common culinary dishes was also highlighted by the proportional piling exercise – see Figure 3-3 and the footnote to Table 3-6 for examples of dishes). Participants explained that there was little way of knowing on purchase whether *mtindi* had been made from raw or boiled milk, shedding light on why such a high proportion of consumer survey respondents were unsure how the *mtindi* they consumed had been produced (Figure 3-4).

Packaged products had a low level of consumption, as did products such as cheese, butter, and cream. There was little evidence of these more Western style dairy products being perceived as aspirational or becoming more popular as income or socio-economic status increased. Rather, multivariable analysis showed that higher socio-economic status was associated with increased frequency of consumption of boiled unpackaged milk (Table 3-7). This supports findings from our qualitative investigations. Respondents from five of twelve interviews and two of eight group discussions reported that there was an association between income and dairy product consumption, explaining that while milk and *mtindi* were perceived to be important to the regular diet, financial constraints could limit consumption:

> *"We don't eat [dairy products] every day because of budget restrictions. We buy food for the day, but if we have to buy milk on top of that it is quite expensive, so we cut down the amount of milk we buy so we can afford other foods."*
> **In-depth interview with consumer survey respondent 00LON02, Longuo ward, 15 November 2013**

Such constraints are unsurprising, given that in urban regions of Tanzania, food expenditure amounts to 90.4% of the household budget for the poorest quintile of the population (76.3% for the richest)(Chauvin, Mulangu and Porto, 2012). Financial constraints have been identified as a barrier to dairy consumption in other parts of East Africa, including Kenya (Omore *et al.*, 2000; Argwings-Kodhek *et al.*, 2005; Musyoka *et al.*, 2010; Njarui *et al.*, 2011; Cornelsen *et al.*, 2016) and Ethiopia (Melesse and Beyene, 2009; Bekele, Beuving and Ruben, 2015).

Table 3-7 Results of multivariable analysis investigating boiled milk consumption

	Coefficient (95%CI)	Odds Ratio (95% CI)	P Value	Design effect
No. children under 5 years	0.59 (0.09 – 1.09)	1.81 (1.10 – 2.97)	0.025	0.74
Socio-economic status				
Poorest	Reference			
Poor	0.68 (-0.10 – 1.24)	1.96 (1.10 – 3.48)	0.026	0.23
Middling	0.89 (-0.15 – 1.64)	2.44 (1.16 – 5.15)	0.024	0.41
Rich	1.51 (0.71 – 2.30)	4.53 (2.04 – 10.07)	0.002	0.44
Richest	1.71 (0.57 – 2.85)	5.52 (1.77 – 17.22)	0.008	0.57
Cut 1 (95% CI)	-1.77 (-2.50 – -1.03)		0.000	0.42
Cut 2 (95% CI)	0.86 (0.30 – 1.43)		0.007	0.34

The output above is for an ordered logistic regression model. Unlike standard logistic regression where the predicted outcome is binary, ordered logistic regression can yield probabilities for an ordinal outcome variable. In a general ordered logistic regression model, the predicted probability of a particular observation j being in category i can be calculated from the regression coefficients (β) and cut points (cut_i) using the equation;

$$\Pr(\mathrm{outcome_j} = \mathrm{i}) = (\mathrm{cut_{i-1}} \leq \beta_1.\mathrm{x_{1j}} + \beta_2.\mathrm{x_{2j}} + \cdots + \beta_K.\mathrm{x_{Kj}} + \mathrm{u_j} \leq \mathrm{cut_i})$$

where $\mathrm{outcome_j}$ *is the response variable that can take ordinal values* i=1,2,…,M *over* N *observations*; $\mathrm{x_{1j}}, \mathrm{x_{2j}}, \ldots, \mathrm{x_{Kj}}$ *are* k *explanatory variables; and* $\mathrm{u_j}$ *represents a logistically distributed random variable.*

Thus the model parameters that need to be estimated are the k *regression coefficients* $\beta_1, \beta_2, \ldots, \beta_k$ and (M+1) *cut points* $\mathrm{cut_0}, \mathrm{cut_1}, \ldots, \mathrm{cut_M}$. *These parameters can then be used to estimate odds ratios. The interpretation of an estimated odds ratio is: the odds for being in an outcome group greater than* k *compared to being in an outcome group less than or equal to* k *is the estimated odds ratio times greater for a one unit change in the predictor variable, keeping all other variables in the regression model fixed.*

In this model, we have a three level ordinal outcome variable ("never consumed boiled milk/ consumed boiled milk less than weekly/consumed boiled milk weekly"). Explanatory variables are: the number of under five year olds in the household as a continuous predictor; and a five level ordinal measure of asset ownership as an indicator of socio-economic status. As there are three categories in the outcome variable, there are two estimated cut-points as an output from the model: Cut 1 and Cut 2. Table 3-7 presents parameter estimates for the model; including the two cut points, the regression co-efficients corresponding to each explanatory variable, and the related odds ratio. Odds ratios can be interpreted as per the following example: the odds of drinking boiled milk weekly compared to drinking boiled milk less often is 4.53 times greater for Rich households compared to Poorest households, provided the number of under 5 year olds in each household is the same.

Higher levels of food security were associated with increased frequency of consumption of boiled milk, however this was not statistically significant (Table 3-8).

Table 3-8 Food security and frequency of consumption of boiled milk

	Frequency of consumption of boiled milk (n, %)		
Food security level	**Never**	**Less than weekly**	**At least weekly**
Little or no hunger in the household (n=132)	5 (3%)	44 (29%)	83 (55%)
Moderate hunger in the household (n=18)	2 (1%)	7 (5%)	9 (6%)
Severe hunger in the household (n=1)	1 (1%)	0	0

3.4.3 Factors driving dairy product choice

The continued preference for unpackaged, traditional dairy products in the diet could be misconstrued as residents being “set in their ways” and displaying a lack of interest or awareness in dairy product safety. On the contrary, our results found that consumers made sophisticated choices with regard to inclusion of dairy products in their diets, and were highly motivated by health considerations when deciding which dairy products to include and where to acquire these products. In group discussions and in-depth interviews, the fundamental contribution of dairy products to good health was universally cited as a reason why Moshi residents considered dairy products important to their diets. There were varied explanations of the ways in which dairy products made this contribution, most commonly the fulfilment of nutritional or dietary requirements (Table 3-9). In some cases, respondents specifically made reference to the proteins, fats and vitamins that were present in milk and *mtindi*. A second set of explanations related to bodily power: dairy product consumption increased strength, energy, and also “heat” in the body. This set of explanations may relate to traditional Chagga concepts of *horu*, loosely translated as bodily power, strength or force (Myhre, 2013, p. 119). As described by Myhre (2007, page 317), an anthropologist who has conducted extensive research with Chagga-speaking communities in Rombo, a district adjacent to Moshi Municipality: *“Foods that are high in power increase the horu of the person, and thereby his or her bodily heat, mrike. These processes take place by increasing the amount of blood, samu, in the body and making it circulate* *faster. For this reason, people emphasize the importance of consuming meat, beer, milk and other 'powerful' foods during the cold season. …Thus, bodily heat and power are….exchanged between humans and animals through blood and milk."*

Although Myhre's research relates to a rural Chagga community, given the high degree of movement back and forth between urban Moshi and the surrounding rural villages where family members still live, it is likely that such concepts persist in the urban space. One of the interviewees who mentioned "heat" specifically was Chagga; the other instances in which the term came up were in group discussions where respondents' tribe was neither known nor recorded.

Dairy product consumption was also linked positively to growth, and to the health of various body systems including: improved digestion; detoxification of the body; improved immunity; and chest health.

Table 3-9 Explanations given for the benefits of consuming dairy products

Explanation	Number of group discussions in which mentioned (n=8)	Number of interviews in which mentioned (n=12)	Total
DIETARY REQUIREMENTS			
General nutrition	2	3	5
Protein	2	2	4
Fat	1	2	3
Vitamins/minerals	3	3	6
Total			18
BODILY POWER			
Strength	2	5	7
Energy	1	2	3
Heat	3	1	4
Total			14
GROWTH			
Builds body	1	0	1
Growth	1	3	4
Total			5
BODY SYSTEMS HEALTH			
Detoxification	2	1	3
Digestion	2	0	2
Immunity	0	2	2
Chest health	2	1	3
Total			10

Thus, our research participants consistently stated that health benefits, particularly nutritious properties, were the main reason for including dairy products in the diet. This finding is consistent with other recent research in the region. For example, work by Haesler *et al.* (2017a; 2017b) into rural and urban consumers' attitudes towards milk in Morogoro region, Tanzania, found that consumers considered milk and *mtindi* to be highly nutritious products, causing good growth and energy, increased body weight, improved health, good mental capacity and fast learning in children. In a study investigating ASP consumption in two low-income areas of Nairobi, Cornelsen *et al.* (2016) found that nutrition was the most frequently stated reason for consuming cow milk (68% consumers) and the second most frequently stated reason for consuming fermented milk (45% consumers). In Malawi, Akaichi *et al.* (2016) similarly found that urban dwellers consumed milk because they perceived it as nutritious, and also because it provides energy.

Moshi Municipality residents also demonstrated a concern for food safety when making dairy food choices. This was reflected in the widespread practice of boiling milk before consumption. In all group discussions and interviews, respondents reported that they always boiled milk before consumption and expected that all or almost all people living in town did the same. The sources from which consumers acquired the knowledge that boiling milk was good practice in terms of food safety were variable and somewhat vague. There is very little by way of either academic or grey literature on the history of public health messaging around food systems in Tanzania or East Africa, nor around boiling milk in particular. In 2003, the Food and Agriculture Organization held an Expert Consultation on Community-based Veterinary Public Health Systems (FAO 2004). The proceedings published from this consultation included a report on community public health education in Tanzania, specifically focussed on zoonoses. The report suggested that consumer knowledge around FBD and food safety was severely lacking across the board. This claim was somewhat contradicted by the information that urban consumers of milk tended to boil milk before consumption, while rural counterparts did not; however, the report did not examine why urban consumers behaved differently. The report concluded with several suggestions as to how to improve food safety through different routes of public health messaging (e.g. through community animal health workers; schools, religious and political forums; and TV/radio campaigns); however, it is unclear to what degree these suggestions were followed up. In the interviews we conducted with consumers (n=12), the most common answer to the question “Where did you learn to boil milk before consuming it?”, was that it was simply habit or behaviour picked up from their parents (n=9); followed by information from health clinics (n=5) and from schools (n=4).

These responses correlate with personal communications I had with key dairy stakeholders[6]. These discussions suggested that there had been no co-ordinated public health campaigns in the past decades encouraging people to boil milk before consumption; instead, any structured campaigns (such as an annual publicity campaign run by the Tanzania Dairy Board on World Milk Day in June) have focussed on encouraging people to drink processed milk as a way to ensure food safety (Omore 2018, pers comm; Kurwijila 2018, pers comm; Mlay 2018, pers comm). However, the stakeholders explained that urban consumers were long habituated to boiling milk before consumption as a way of prolonging shelf life and improving food safety (Omore 2018, pers comm; Mlay 2018, pers comm), and reported that Tanzanians were advised at health clinics regarding the need to boil milk before consumption, particularly pregnant women receiving antenatal classes (Kurwijila 2018, pers comm; Mlay 2018). Targeting pregnant women is likely to be a successful public health strategy as not only do women consume higher volumes of milk in the postnatal period, but they are also likely to take on responsibilities for food preparation for the family. In addition, the need to boil milk was included in the curriculum of primary and secondary schools (Kurwijila 2018; pers comm). Some of these sources are also alluded to in the literature; for example reference being made to messages surrounding boiling milk as a means to prevent tuberculosis being disseminated at medical facilities (Mfinanga *et al.*, 2003b) and at maternal and child health clinics (Mfinanga *et al.*, 2003a). However, for all of these routes of message transmission, it was unclear how the information was communicated (e.g.

[6] Prof Lusato Kurwijila, Chair of the Tanzania Dairy Board; Dr Amos Omore, veterinary epidemiologist with expertise in East African dairy value chains, International Livestock Research Institute; Ms Deogratius Mlay, Manager of the Dairy Technical Services Dept, Tanzania Dairy Board

written or oral) or whether the safety of *mtindi* or other dairy products potentially made from raw milk was factored into the messages.

Although the practice of boiling milk was widespread, it was not entirely universal. In the consumer survey, two respondents reported consuming raw milk, both less than weekly (one of whom explained she craved it when she was pregnant but would never otherwise drink it), and two further respondents reported consuming raw milk with other foodstuffs (one of whom explained that she added fresh raw milk to boiling porridge for breakfast). Reported consumption of products made from raw milk was universally low, although notably, approximately 90% of unpackaged *mtindi* consumers did not know whether the *mtindi* they consumed was made of boiled or raw milk (Table 3-5 and Figure 3-4). Furthermore, in one focus group, three respondents raised reasons why some groups might not boil milk before consumption:

> ***Respondent B:*** *People believe that milk which is not boiled can treat child malnutrition; that is mostly why people do not boil milk.* ***Respondent C:*** *For local breed cows it's OK if you don't boil milk, compared to modern breeds where you have to boil because for this type of cattle, their food is different from local breeds hence why you should boil.* ***Respondent F:*** *Most elderly people do not like boiled milk; after milking they just store it in a calabash ready to be used.* **Group discussion, Mji Mpya ward, 16 November 2013** ***(see Appendix 2, section 3 for index of group discussion participants)***

Food safety concerns were also evident in residents' choices regarding where to acquire dairy products. Both milk and *mtindi* were available from a wide range of outlets (Table 3-10). These included urban livestock keepers (town residents who kept typically one to three cows for milk sale); itinerant traders, who comprised both informal intermediary traders ("hawkers") and sellers from registered dairy co-operatives; small kiosks or shops in residential areas; one bi-weekly market selling mainly *mtindi*; and one Western-style supermarket. Both the consumer survey and proportional piling identified shops as the most frequent source of dairy product acquisition, followed by itinerant traders (Table 3-10 to Table 3-12). While univariable analysis did not detect any significant associations that would predict where respondents acquired their dairy products from (data not shown), the group discussions and in-depth interviews allowed us to explore in more depth what factors governed these choices (Table 3-13). The most frequently cited factor was cleanliness and hygiene, closely followed by history of adulteration. Participants stressed the importance of good hygiene and cleanliness at all stages of dairy production, from the process of milking the cow, to the containers in which the product was stored, to the cleanliness of a vendor's measuring utensils or even the vendor him/herself. Adulteration was a concern in all study wards, the most common complaint being milk being mixed with water to increase quantity. However, other materials used to adulterate milk or *mtindi* were reported to include vinegar, wheat flour, maize flour, ground baobab nuts, and yeast. Concerns about cleanliness, hygiene and adulteration when choosing a dairy product vendor were expressed more frequently than concerns about the sensory properties of the product (e.g. good taste or texture), and were far more commonly cited than qualities such as reliability, convenience or price (Table 3-13). Our findings are consistent with a consumer study conducted in two other Tanzanian regions, in which participants rated hygiene and cleanliness as the main attributes to judge milk quality, followed by viscosity as an indicator of adulteration (Haesler et al., 2017).

Table 3-10 Place of acquisition of dairy products for respondents buying product at least weekly (N=151)

	Total who consume at least weekly	Produce own	Urban livestock keeper	Any itinerant trader	Market	Shop	Super-market	Café, bar or restaurant
		n, % (95% CI)	n, % (95% CI)	n, % (95% CI)	n, % (95% CI)	n, % (95% CI)	n, % (95% CI)	n, % (95% CI)
Unpackaged milk	92	5, 5.5 (1.2-22.3)	18, 20.5 (6.9-27.3)	25, 26.6 (15.6-41.6)	1, 1.0 (0.1-9.0)	59, 63.7 (47.1-77.6)	0	1, 1.0 (0.1-8.5)
Unpackaged *mtindi*								
• **Made from raw milk**	3	2, 68.3 (0.3-99.9)	1, 31.7 (0.1-99.7)	0	0	0	0	0
• **Made from boiled milk**	8	3, 36.8 (5.3- 85.8)	2, 28.8 (1.2-93.1)	2, 3.8 (23.5-70.3)	0	1, 11.0 (0.6-73.0)	0	0
• **Not sure if made from raw or boiled milk**	56	0	7, 12.3 (3.8- 33.5)	12, 21.1 (10.9- 36.8)	3, 5.1 (1.6-14.9)	42, 75.3 (56.4-87.8)	0	0
• **Any kind of unpackaged *mtindi***	66	5, 7.8 (2.9- 19.2)	10, 15.5 (5.4-36.9)	14, 20.7 (11.2-35.2)	3, 4.3 (1.4-12.4)	43, 65.1 (42.8, 82.3)	0	0
Chai (milky tea)	50	46, 92.0 (75.8-97.7)	0	0	0	0	0	0
Packaged milk	7	0	0	0	0	3, 45.3 (5.3-92.5)	5, 67.8 (7.3-98.3)	0
Packaged *mtindi*	5	0	0	0	0	0	4, 77.3 (3.3-99.7)	0
Packaged cream, cheese or butter	2	0	0	0	1, 50 (0-100)	0	1, 50 (0-100)	0

Butter made from raw milk	1	0	0	0	1, 100 -	1,100 -	0	0
Cheese/butter/other, not sure if raw/boiled/pasteurised	3	0	0	1, 31.9 (0-100)	0	1, 31.9 (0-100)	1, 36.2 (0-100)	0

Table 3-11 Results of proportional piling exercises exploring place of acquisition of dairy products

Ward	Place of acquisition	Unpackaged milk		*Mtindi*	
		n	**%**	**n**	**%**
Boma Mbuzi	Urban livestock keeper	3	60	1	14
	Produce own	0	0	3	43
	Cafeteria	0	0	0	0
	Shop	2	40	3	43
	Supermarket	0	0	0	0
Korongoni	Urban livestock keeper	3	20	4	36
	Produce own	6	40	2	18
	Shop	6	40	5	45
Longuo	Cafeteria	0	0	0	0
	Market	7	39	7	100
	Itinerant trader	0	0	0	0
	Shop	11	61	0	0
	Supermarket	0	0	0	0
Majengo	Urban livestock keeper	0	0	3	21
	Produce own	1	8	1	7
	Shop	12	92	10	71
	Supermarket	0	0	0	0
Mji Mpya	Shop	6	67	5	83
	Urban livestock keeper	0	0	0	0
	Supermarket	0	0	0	0
	Itinerant trader	3	33	1	17
Njoro Moshi	Urban livestock keeper	0	0	0	0
	Produce own	4	33	3	33
	Market	1	8	0	0
	Itinerant trader	3	25	2	22
	Shop	4	33	4	44
	Supermarket	0	0	0	0

Table 3-12 Number of times a particular type of place of acquisition was listed in the top three of places to acquire unpackaged milk or mtindi during proportional piling exercises (N=6)

Place of acquisition	Number of times in top three	
	Unpackaged milk	***Mtindi***
Shop	6	5
Home	3	4
Urban livestock keeper	2	3
Market	2	1
Supermarket	0	0
Cafeteria	0	0

Table 3-13 Reasons given in interviews and group discussions for choosing a particular dairy product vendor

Explanation	Number of group discussions in which mentioned (n=8)	Number of interviews in which mentioned (n=12)	Total
Cleanliness/hygiene	7	8	15
Adulteration	4	10	14
Sensory properties of product	4	9	13
Reliability	2	6	8
Convenience	3	6	9
Price	3	1	4

A sizeable proportion of survey respondents (42.5%, 95%CI 32.2%-53.5%, n=64) reported that they always acquired their dairy products from the same source. The group discussions and interviews suggested that those who did not instead built up a repertoire of sources, based on their personal experience. For example, if a person discovered that milk had been adulterated with water, they would avoid that vendor in future. The role of trust in governing the milk and *mtindi* value chains will be explored more in Chapter 5; suffice here to say that the development of a relationship of trust between customer and vendor was key in order for consumers to repeatedly return to a particular vendor. The influence of these relationships could be strong; one consumer even reported that she would prefer not to buy milk or *mtindi* than have to source these products from a different vendor:

> ***When [your supplier] is sick and you might buy milk from somewhere else, are there any places that you absolutely wouldn't buy milk from?***
> *I can't really buy from anyone else, not because I don't want to but because I trust the woman, and if she is not able to come for two or three days it's not a problem, staying two or three days without milk is not a problem, so I'll just wait.*
> ***So you'd prefer, actually, if there was an interruption with your regular supplier, you'd prefer not to have any milk and wait till the supplier's back than to get it somewhere else?***
> *Yes.*
> **In-depth interview with participant 01MIE08, Miembeni ward, 22 November 2013**

For people who were newcomers to an area and were yet to establish such relationships of trust, our findings indicated that personal recommendation from other neighbours might be an important way to link in with dairy sales in the area[7]. For example, one interviewee whom we met through the consumer survey had moved to the area from another part of Moshi Municipality ten months previously, and at the time of survey was not drinking any milk products at all - even though he said he considered them very important to his diet. We returned a few weeks later to interview him, and he had since found a vendor he was satisfied with and was now drinking milk every day:

> *So actually, lately I just tried to inquire from people actually if the milk [from a local shop] was safe, especially the people who were staying here [indicated the compound he lived in], they said the milk was very safe, the guy is very clean, so actually they also prefer taking the milk there…*
> ***So how come it took you ten months to find…or eleven months….to find somewhere to buy milk from?***
> *I think it's because of my own temperament, because it takes time to trust somebody, and I just knew that to shift appropriately from that woman [from whom he used to buy milk at his former home] to finding…I just knew that actually there's not so many people selling milk who are that hygienic…So actually I was not moved to find - I would rather not drinking milk than opt to take milk from a place where I don't know…*
> **In-depth interview with participant 02MAJ19, Majengo ward, 20 December 2013**

[7] The role of social capital (the resources that are available to an individual as a function of their being socially connected to others) in governing dairy value chains will be explored further in Chapter 5.

Another woman living in the same area had moved there less than six months previously from Morogoro region with her infant daughter and home help. She also indicated the importance of personal contacts and local recommendations when electing where to buy dairy products[8]:

> ***Your grandmother taught you that good milk is that from one or same cow, then why don't you buy milk from a local farmer?***
> *Because I'm still a newcomer in this area I don't know many people, also because I'm working I'm not here a lot and when I get back I go inside to rest so don't have much interaction with people. So I'm still looking for and researching the environment.*
> **In-depth interview with participant 02MAJ17, Majengo ward, 22 November 2013**

The above two instances suggest that people moving to and within town were cautious about where to source their dairy products and could take some months to research their environment, make personal contacts with local neighbours and seek recommendations before their buying habits became established. This theory is supported by the consumer survey finding that respondents from newly established households (those that had resided at the address for less than five years) were significantly more likely to always buy dairy products from the same source. For this group, the odds of acquiring dairy products from the same source each time for was almost twice that of well-established households (Table 3-14).

Table 3-14 Logistic regression model exploring association between household establishment and acquiring dairy products from the same vendor
Outcome variable: Always buys dairy products from same vendor (Yes/No)
Explanatory variables: "Well established"= at least one resident living at address for ≥5 years
"Newly established" = no one resident living at address for 5 years or more

	n	OR	95% CI	p
Well established household	81	Reference		
New household	64	1.92	1.03 – 3.61	0.04

The care that Moshi residents demonstrated in being sure to acquire dairy products only from known and trusted sources, together with the large emphasis placed on cleanliness, hygiene and adulteration when choosing those sources,

[8] Note that while this woman was identified through the consumer survey fieldwork, she did not participate in the survey itself as she was ineligible, having lived in the area less than six montha. However, our initial interaction and discussions convinced me to re-visit her to interview her in more depth.

suggest that these consumers had food safety at the forefront of their minds when selecting where to acquire dairy products. Indeed, there were some indications that part of the reason that consumers preferred traditional dairy products to more modern counterparts was precisely because they perceived them as safer for health. Examples of this included expressed preferences for milk from local breed cows (rather than improved cross-breeds), or for drinking milk from only one cow rather than bulked:

> *I like milk from local cows that is why I have an order from this lady, because improved breeds use a lot of drugs and chemicals compare to the local breed. Local breeds are more safe.*
> **In-depth interview with consumer 01MIE08, 22 November 2013**

> ***Is the milk from local breed cows and hybrid breed cows different?***
> *Yes, there is a great difference because milk from local breeds is strong and thick compared to the improved breeds, which is very light.*
> ***Do you think one is healthier than the other?***
> *Yes, because for local cows they don't feed food with chemicals, and is not zero grazing so the local cows are healthier than improved cows because they are fed with food that contains a lot of chemicals.*
> **In-depth interview with consumer 05BOM02, 20 December 2013**

> ***Where would you not get dairy products from?***
> ***Respondent G:*** *The market because I am not sure of the quality of milk, like hygiene; also because milk that is obtained from the market is a mixture of milk from different cows* ***All other respondents*** *supported this answer.*
> **Group discussion in Korongoni ward, 6 November 2013**

In addition to these formal findings, I came across similar preferences in relation to eggs during my time in Tanzania. Over these periods, I developed a close relationship with my housekeeper, who took on a sense of responsibility for ensuring my welfare while I was away from home. As our friendship developed, she began to bring me eggs from her chickens in order that I would not have to eat shop-bought eggs, which she considered inferior in quality owing to their being "*wa kisasa*" i.e. produced by modern methods. Later on, my Kiswahili teacher also started in the egg business with a farm of approximately one hundred chickens. He offered to bring me a weekly order of eggs, but was at pains to point out that despite the size of his farm, the eggs were safe, produced in a natural way, and not to be considered "*wa kisasa*". The perceived problem with "*wa kisasa*" methods seemed to be the use of intensive methods, especially of drugs or of chemicals in feeds which could then prove detrimental to human health. These conversations reminded me of the increasing popularity of and trust in organic, traditionally produced foods at home in the UK. Grace (2015) notes that in low and middle income countries, there is a high level of concern amongst the general public about the presence of chemicals in food. Our research certainly suggested that, far from being perceived the safer option, pasteurised packaged milk products could be considered *"wa kisasa"* products and therefore unsafe and not to be trusted. Conversely, "traditional" products such as unpackaged milk and *mtindi* would be considered the more wholesome, healthier option. Consumers' perceptions and practices regarding the risks posed by dairy products to health is a theme that will be revisited in Chapter 6.

3.4.4 Consumption patterns within population groups

> *All people in the family consume dairy products, but children are given the first priority.*
> **In-depth interview with consumer survey respondent 02MAJ21, Majengo ward, 22 November 2013**

Table 3-15 shows the population groups cited in group discussions and in-depth interviews as consuming more dairy products than the general population. The group most frequently cited was children. This finding was corroborated by the consumer survey, where multivariable analysis demonstrated that increased frequency of boiled milk consumption was significantly higher in households with a greater number of children aged under 5 in the household (Table 3-7). Respondents considered that milk was important to children's diets owing to its nutritious properties that would help children grow and become strong and robust; milk was also described as a breastmilk substitute and suitable weaning food. Other studies in Tanzania and the wider region have also demonstrated increased milk intake by children compared to the general population (Weliwita, Nyange and Tsujii, 2003; Njarui *et al.*, 2011; Akaichi, Chalmers and Revoredo-Giha, 2016). A review of the ASP nutrition literature by Neumann *et al.* (2002) has shown this to be a nutritionally sensible strategy, as increased milk consumption leads to diverse benefits for children, such as improved physical growth, cognitive function and educational attainment.

Table 3-15 Demographic groups consuming more dairy products compared to the general population, as reported in interviews and group discussions

Explanation	Number of group discussions in which mentioned (n=8)	Number of interviews in which mentioned (n=12)	Total
Children	8	10	18
Mothers of newborn babies	6	7	13
Sick	4	5	9
Elderly	6	1	7

The next most frequently cited group was mothers of newborn babies. Respondents explained that women who had recently given birth should consume more dairy products, both to increase their strength and to ensure an adequate supply of breast milk for the newborn child.

> *" …when one gives birth is important to use things that contain fat so as to increase heat in the body and get strong."*
> ***In-depth interview with consumer survey respondent 08KOR21, Korongoni ward, 12 December 2016***

Again, similar local explanations were described by Myhre (2013; 2007; 2006) during his work with rural Chagga communities in Rombo district: *"Newly delivered women therefore remain in confinement for up to three months, staying in bed with their babies and receiving different, 'powerful' foods. These foods replenish the blood, heat and power lost during childbirth. They also increase a woman's lactation, enabling her to nurse her child, thus contributing to its horu." (*Myhre 2007, page 320*)*. Again, Neumann et al's review (2002) suggests that it is a sensible nutritional strategy for women who are breastfeeding to increase consumption of ASPs.

The sick were the next most commonly cited group as consumers of large amounts of dairy products. Respondents explained that milk and *mtindi* were not administered as medicine *per se*, but were considered to be nutritious foods that could replenish strength and energy, and that were easy for a sick person to consume because they were soft and did not require chewing. For these reasons, dairy products were viewed as important to combat illness in general, rather than for specific diseases. The exception to this was people with stomach ulcers: in two group discussions and one interview, respondents reported that milk consumption was thought to alleviate the symptoms of this condition. Finally, the elderly were also identified as a group consuming large amounts of dairy product. Again, this was due to dairy products being considered as nutritious and strength-giving, although one group discussion participant added that elderly people needed dairy products in their diet to assure good digestion.

Our results demonstrate that consumption of dairy products was higher in population groups that are in need of improved nutrition, demonstrating that Moshi residents were aware of the many health benefits that inclusion of dairy products in the diet can bring. However, these same vulnerable groups are also at increased risk of FBD, as their immune systems tend to be weaker than the general population (Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016a). This increased risk could be exacerbated by the increased exposure to potentially unsafe dairy products due to higher levels of dairy consumption in these groups.

3.5 Conclusion

We found that unpackaged milk and *mtindi* – fermented milk – were by a large margin the two dairy products most frequently consumed by Moshi Municipality residents. Western style packaged or pasteurised products were not frequently consumed even amongst higher income groups; in contrast, our data showed that increasing socio-economic status was associated with increasing frequency of consumption of unpackaged milk. However, the persistent preference for these traditional products over more modern pasteurised products did not reflect a lack of interest in health issues related to dairy products. Consumers made sophisticated choices that displayed both an awareness of the health benefits that dairy products could offer and concern for the FBD risks they might pose – for example, the anxiety around harmful chemicals in food resulting from modern farming practices; the importance of cleanliness and hygiene and lack of adulteration together with the critical role of trust when selecting milk and *mtindi* vendors; and the reported widespread practice of boiling milk before consumption. However, our research found that *mtindi* was not necessarily made from boiled milk and could not be boiled before consumption, thus potentially posing different (and perhaps greater) disease risks to those posed by milk. Moreover, we found that the population groups that were consuming the highest amounts of dairy products (namely: infants and young children, postnatal and breastfeeding women, the sick, and the elderly) were also those who are most vulnerable to the risks of FBD (Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016a).

4 Structure of the principal dairy value chains serving Moshi Municipality

4.1 Summary

Elucidating the structure of an ASP value chain can expose vulnerabilities within the chain that could foster the introduction and propagation of pathogens harmful to health. Investigating the structure of the milk and *mtindi* value chains supplying Moshi Municipality revealed that both value chains featured a rural-to-urban strand, where the product was made in the rural area surrounding the town and transported into the town for sale, and an urban-to-urban strand where the product was made and sold in the town. The rural-to-urban strand predominated in both cases, although in the *mtindi* value chain the urban-to-urban strand provided an important route to offset potential losses whereby unsold milk was left to sour naturally into *mtindi* that could then be sold on. Given the universal lack of cold chain and unhygienic conditions of milk transport and sale, it is likely that leftover milk would have been highly contaminated with pathogens. The milk and *mtindi* value chains each involved similar value chain nodes, with a high degree of interlinkage and potentially multiple points of transaction between different actors on the journey from cow to consumer. The distinction between the formal and informal sectors was blurred both in terms of actors involved and of the disease risk-driving and risk-mitigating practices undertaken by those actors. Each value chain strand potentially posed different risks to consumers as they represented different risk pathways through which milk or *mtindi* could become contaminated. In the case of milk, the value chain strand through which the milk had originated was usually obvious to consumers, who could further mitigate their risk by boiling milk before consumption. In the case of *mtindi*, the value chain strain through which the *mtindi* had originated was often not clear; neither was it easy to discern whether *mtindi* was made from raw or boiled milk. Given that *mtindi* is consumed as purchased and there is no preparatory risk-mitigating step equivalent to boiling before consumption, the structure of the *mtindi* value chain may be placing consumers at higher risk of food-borne infections compared to that of milk.

4.2 Introduction

Evaluating the risk posed by food-borne disease (FBD) to urban consumers in developing countries is hampered by two main barriers: lack of data on the urban diet, and lack of established methodologies to systematically assess FBD risk along food value chains (Grace *et al.*, 2008; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). The latter can be partly explained by the challenges involved in applying international systems of risk assessment designed for the formal, regulated, integrated food value chains seen in developed countries to the informal, unregulated and shifting value chains common in developing countries (Grace *et al.*, 2008; Costales, Pica-Ciamarra and Otte, 2010). These challenges are perhaps particularly great when considering the risks of animal source products in urbanising areas, where livestock production systems are continually forced to evolve and adapt in order to meet the changing and growing demands of urban consumers (United Nations Human Settlements Programme, 2008; de Haan, Gerber and Opio, 2010; Gerber *et al.*, 2010; Neumann, CG *et al.*, 2010).

VCRA seeks to overcome these challenges by integrating systematic risk assessment approaches with value chain analysis, which serves to map and characterise the food systems in which FBD risk can occur. The approach has as its premise that in order to investigate how a disease might arise and spread in a value chain, it is first necessary to obtain a comprehensive understanding of the structure and function of that value chain (Food and Agriculture Organization, 2011). This characterisation then acts as an underpinning framework for subsequent systematic evaluations of risk. Elucidating the structure of an ASP value chain can be invaluable to identifying structural vulnerabilities which can exacerbate FBD risk (Alarcon *et al.*, 2017).

Our work in Moshi Municipality revealed that the two most consumed dairy products by residents of the area were unpackaged milk and *mtindi*. In order to explore questions regarding the potential of these products to pose food-borne infectious disease risks, the next step was to trace the origins of these products from cow to consumer through conducting a detailed analysis of the principal value chains supplying them to Moshi Municipality.

The dairy trade in Tanzania has a somewhat complicated history. After becoming an independent republic in 1961, the operations of the dairy industry were led by a National Dairy Board which had full responsibility for co-ordinating and regulating the development of the industry. In 1967, all large scale farms and dairy processing units (DPUs) were nationalised, and during the 1970s a number of parastatal organisations were established to manage dairy activities. Following liberalization of the economy in the mid-1980s to mid-1990s, these organisations were dissolved and the government withdrew from involvement in the dairy industry, promoting instead the involvement of the private sector. However, this was not accompanied by regulatory reform and the informal dairy sector grew rapidly (Kifaro, 2010; Charles and Mchau, 2011).

More recent policy shifts have seen a move towards governmental support of the dairy industry through investment in production, processing and the formation of dairy organizations (Kifaro, 2010; Ministry of Livestock and Fisheries Development, 2011). Notwithstanding these policies, several studies have shown the informal sector to continue to handle the highest proportion of milk, with the percentage of formally processed milk being sold estimated at as low as 0.2% in the central corridor, to 20% in Iringa in the southern Highlands (Fussi, 2010; Kifaro, 2010). National statistics estimate that 90% of milk is marketed informally, and only 2% processed, with the proportion of marketed milk being processed having decreased over recent decades (Charles and Mchau, 2011; International Livestock Research Institute and East Africa Dairy Development/Tanzania Dairy Survey, 2012; TechnoServe, 2012). Whether these proportions differ in urban compared to rural areas is unclear, as all of these studies consider milk sales at a regional or national level. The starting point for all of these studies was upstream in the value chains (e.g. farmers and processors), tracing milk sales forwards regionally and nationally, as opposed to my research which positioned the urban consumer as a starting point and traced backwards. There are few studies that examine dairy value chains supplying urban consumers specifically. However, one study investigating milk value chains supplying Mwanza city, northern Tanzania, confirmed that informal value chains continued to predominate even in this urban area (Alexopoulou 2011). Moreover, the study demonstrated a significant overlap between the formal and informal dairy sectors, a finding supported by reports from other Tanzanian regions

(Mchau *et al.*, 2009; Fussi, 2010; Msuya, 2012). All of these studies considered milk sales only; I found no description of value chains relating to *mtindi* or other fermented milk products in either the Tanzanian or regional literature.

Thus, in addition to the data gap regarding the nature of milk value chains supplying Tanzanian urban consumers specifically, there is also a striking absence of any information on fermented milk value chains, despite their popularity across the East African region (Omore, Arimi and Kang'ethe, 2002; Melesse and Beyene, 2009; Njarui *et al.*, 2011; Haesler, Msalya, Garza, Fornace, Eltholth, Kurwijila, *et al.*, 2017). In this chapter, I seek to characterise the structure of both the milk and *mtindi* value chains supplying urban consumers in Moshi Municipality, and to highlight some of the structural vulnerabilities in these chains that may have implications for FBD risk to consumers.

4.3 Methods

4.3.1 Study locations

Preliminary value chain analysis in the first stage of fieldwork identified Hai district, a rural area in the foothills of Mount Kilimanjaro contiguous with Moshi Municipality district, to be a key supplier of milk and *mtindi* to Moshi town. Rural fieldwork was concentrated in five villages from four wards of this district. These villages were selected purposively following key informant interviews with relevant government officials at Hai district and from the four wards (see Appendix 2 for details). We selected villages that were reported to have high levels of milk production and that reflected a spread of level of organisation of the dairy trade (e.g. presence/absence of a Dairy Processing Unit (DPU) or Milk Collection Centre (MCC)). We also conducted fieldwork in Moshi Municipality, for example at sites of milk/*mtindi* wholesale and retail, or in the wards in which we had conducted earlier fieldwork in the first stage of research. In this way we were able to trace complete value chains along their full length from cow to consumer.

4.3.2 Recruitment

Value chain actors were purposively selected for inclusion within the study. In each rural village we endeavoured to recruit:

- At least one member of staff from each DPU
- At least one member of staff from each MCC
- At least one farmer supplying each DPU/MCC
- Two intermediary traders
- At least one farmer supplying each intermediary trader

This scheme was chosen so that a cross-section of value chain nodes would be represented in each village, i.e. both formal, officially registered nodes such as DPUs and MCCs as well as informal, unregistered intermediary traders. This enabled a fuller characterisation of the value chains, and the opportunity to explore value chain actors' rationale for interacting with one node versus another. The scheme was adapted according to the village (e.g. in one village there were no DPUs or MCCs, so more intermediary traders and their supplying farmers were selected in lieu), and according to logistic constraints. Access to value chain actors was negotiated through village officials and/or staff from the DPU/MCC. Intermediary traders proved difficult to recruit as village officials were often unable to identify which community members were engaged in this work, or to locate them in the village as they worked long days in town. Therefore, we adopted an additional strategy of recruiting intermediary traders by visiting known milk sales points in Moshi Municipality and identifying participants there, rather than searching for them in their home villages. This proved an effective strategy, although as a consequence two intermediary traders included in the study were not from the selected villages, but from Uswaa village in Machame Uroki ward. As this village was close to (within ~5km) the selected study villages, this seemed acceptable.

In Moshi Municipality, we approached market traders and shop workers directly to request their participation in the study. We identified urban livestock keepers for participation either through the relevant ward livestock field officer (LFO) or because they had participated in fieldwork in the first phase of research (e.g. a group discussion or survey).

Through these methods we successfully recruited 13 rural smallholder farmers, two DPUs, five MCCs, 14 intermediary traders, eight market traders, ten shops and four urban livestock keepers to the study, a total of 56 value chain actors.

Consumers are part of the value chain too, and the data we collected from the first stage of fieldwork (described in Chapter 3) were also considered in this analysis.

4.3.3 Data collection

Data collection was conducted in each rural village for a period of approximately 1 – 1.5 weeks, with fieldwork in town fitted around this schedule. We used a combination of methods described below to gather data on the milk and *mtindi* value chains supplying Moshi Municipality. Not all methods were used for each actor; full details can be found in Appendix 2. Data collection tools such as interview schedules and surveys featured questions about the value chain dimensions described in Chapter 2 Section 2.3, i.e. input-output structure, geography, governance, economics, knowledge, non-human actants, and adaptation, as well as questions surrounding disease risk perceptions and practices.

4.3.4 Interviews

We conducted interviews with consumers and value chain actors, and with the following key informants: village, ward and district officials; the chair of the Tanzania Dairy Board; the head of an international development project run by United States (US) dairy co-operative, Land O' Lakes; and a representative from the Tanzania Food and Drugs Authority (TFDA) (Appendix 2). Interviews were semi-structured; examples of schedules can be found in Appendix 3.

4.3.5 Participant observation

Wherever possible, we engaged in direct observation and shadowing of value chain actors' daily activities surrounding the milk trade. For example, this could involve observing a farmer milking and accompanying her to the local MCC; spending the day at a DPU from the time of milk reception through to processing and packaging; or accompanying an intermediary trader when receiving milk deliveries, travelling to town, selling his/her dairy products in town, or clearing up to go home (in some cases, all of the above). Thus periods of observation could last from ten to fifteen minutes to an entire working day[9]. In order to reduce changes in behaviour resulting from the feeling of being "watched", I often recorded field notes after the activities of interest had taken place, and not in the presence of the participant. In such cases, I would record notes as soon as possible after the activity had taken place in order to minimise problems with recall.

4.3.6 Time Use Analysis

In order to explore how value chain actors used their time, I developed a simple table to gather structured data on the daily activities carried out by participants; how long each would take; where the activity would take place; who was involved in each activity; and any supplementary contextual data concerning that activity which may be relevant to the research questions (see Appendix 3). As part of an interview or survey, I asked participants to describe the 24 period of a "typical" working day (usually Monday-Saturday); for market traders, I sometimes took two time use records, one for a market day and one for a non-market day.

4.3.7 Surveys

I developed value chain actor-specific surveys to collect information both on the seven dimensions of the value chain and on themes associated with food safety and health risks outlined by the Codex Alimentarius (CA) (Food and Agriculture Organization; and World Health Organization, 2006; Codex Alimentarius, 2009b; World Health Organization and Food and Agriculture Organization of the United Nations, 2011). Examples of these surveys can be found in Appendix 3. I employed the surveys in two ways: firstly, as a tool to gather information in cases where in-depth interviews were not feasible (e.g. because the respondent had limited time or because the environment was not conducive to conducting a long interview), and secondly to collate all of the data I had obtained from each actor through the methods described above. Therefore, at the end of fieldwork,

[9] Note that the term "participant observation" usually refers to longer observation periods, whereby the researcher seeks to integrate with a community in order to foster an intimate knowledge of its members, activities and practices. However, I use the term here as we both participated in and observed dairy value chain actors' activities, and in some contexts spent relatively long periods of time with research participants and sites (e.g. repeated visits to the market over the entire course of fieldwork).

each value chain actor had a completed value chain risk analysis survey document, regardless of how the information was originally collected (e.g. by in-depth interview or by survey); nonetheless I recorded how the information was collected on this document, as this could be useful to the analysis.

4.3.8 Global Positioning Systems

In order to follow the course of milk and milk products from farm to consumer both temporally and spatially, I took time-stamped (GPS) points and tracks at relevant points during fieldwork using a Garmin e-trex10 device. This could include for example the pin-pointed location of a MCC, the route taken by an intermediary trader from home to his/her sales point in Moshi Municipality, or the locations of known milk sales points within the town.

4.3.9 Analysis

I conducted a thematic analysis of the qualitative data with the aid of NVivo software (QSR International Pty Ltd, 2012) . Having sorted the data by value chain actor, I applied seven etic codes which corresponded to the seven value chain dimensions. I then explored each dimension further by reading through the dataset and applying emic codes generated inductively from the data and organising these into themes. I repeated this process several times until I was satisfied that no new codes or themes were arising. In this way, the data were interrogated both by value chain dimension and by value chain actor. Using these findings, I built value chain maps which linked actors and processes, following the value chain visuals advocated by Springer-Heinze (2008).

I analysed time use data from each value chain actor group separately, generating codes inductively from the primary activity data reported by those actors. In each case, I undertook several iterations through the data until a suitable coding framework had been developed for that group. I developed an Excel spreadsheet which covered a 24 hour period in intervals of fifteen minutes, into which I entered the relevant code for each actor's reported activities during those intervals. Once I had coded the data for each respondent, I inspected the dataset for patterns occurring within that value chain actor group.

I loaded GPS data into geographic information system software (QGIS Development Team, 2016) to facilitate visualisation and spatio-temporal analysis of these data.

4.4 Figures and tables

Table 4-1 Details about the processes undertaken at each value chain stage

Value chain stage	Details
Milking	The practice of milking cows to produce raw milk.
Bulking	The collection of raw milk in large quantities and from multiple sources.
Heat treatment	Heating raw milk to a temperature high enough to ensure pasteurisation. The Codex Alimentarius Standard for Milk and Milk Products (WHO&FAO 2011) defines pasteurisation as “the application of heat to milk and liquid milk products aimed at reducing the number of any pathogenic micro-organisms to a level at which they do not constitute a significant health hazard”, stipulated as a temperature of not less than 72 °C for at least 15 seconds. Boiling milk is sufficient to ensure pasteurisation.
Souring	The process in which milk is transformed into *mtindi*. Souring could occur in two ways: firstly, by leaving raw milk to sour of its own accord with no intervention through the action of lactic acid bacteria (LAB) naturally found in milk; secondly, by first heat treating raw milk and then adding a starter culture containing LAB (which can itself be raw milk) to start the souring process. During the souring process, which takes 24-48 hours, the milk coagulates to form solid curd and liquid whey. *Mtindi* is a mixture of curd and whey; *mtindi* vendors would adjust the proportions of curd and whey by decanting whey to suit customer preference.
Packaging	Decanting milk/*mtindi* into custom-made containers (e.g. plastic bottles or pouches) for retail as individual units.
Transport	The transportation of milk/*mtindi* to Moshi Municipality from surrounding rural areas, or around Moshi Municipality to different points of sale.
Wholesale	The act of selling milk/*mtindi* in large quantities to value chain actors who will thereafter sell it on themselves.
Retail	The act of selling milk/*mtindi* in relatively small quantities direct to the final consumers.

Figure 4-1 Milk value chain: rural-to-urban strand

The chevrons each represent a stage of the value chain where a particular process occurs. Where a chevron has a dotted line, the stage is optional and is not undertaken. The boxes underneath each chevron indicate which value chain nodes undertake this stage.

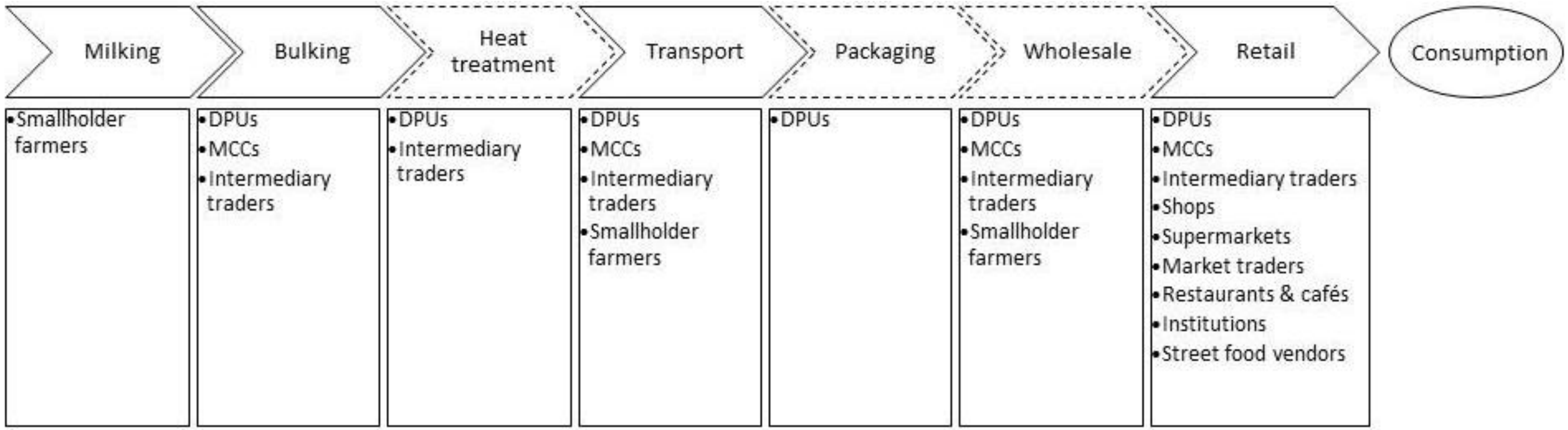


Figure 4-2 *Mtindi* value chain: rural-to-urban strand

The chevrons each represent a stage of the value chain where a particular process occurs. Where a chevron has a dotted line, the stage is optional and is not undertaken. The boxes underneath each chevron indicate which value chain nodes undertake this stage. The grey arrows indicate where a product (i.e. milk or mtindi) might skip or return to a stage of the value chain.

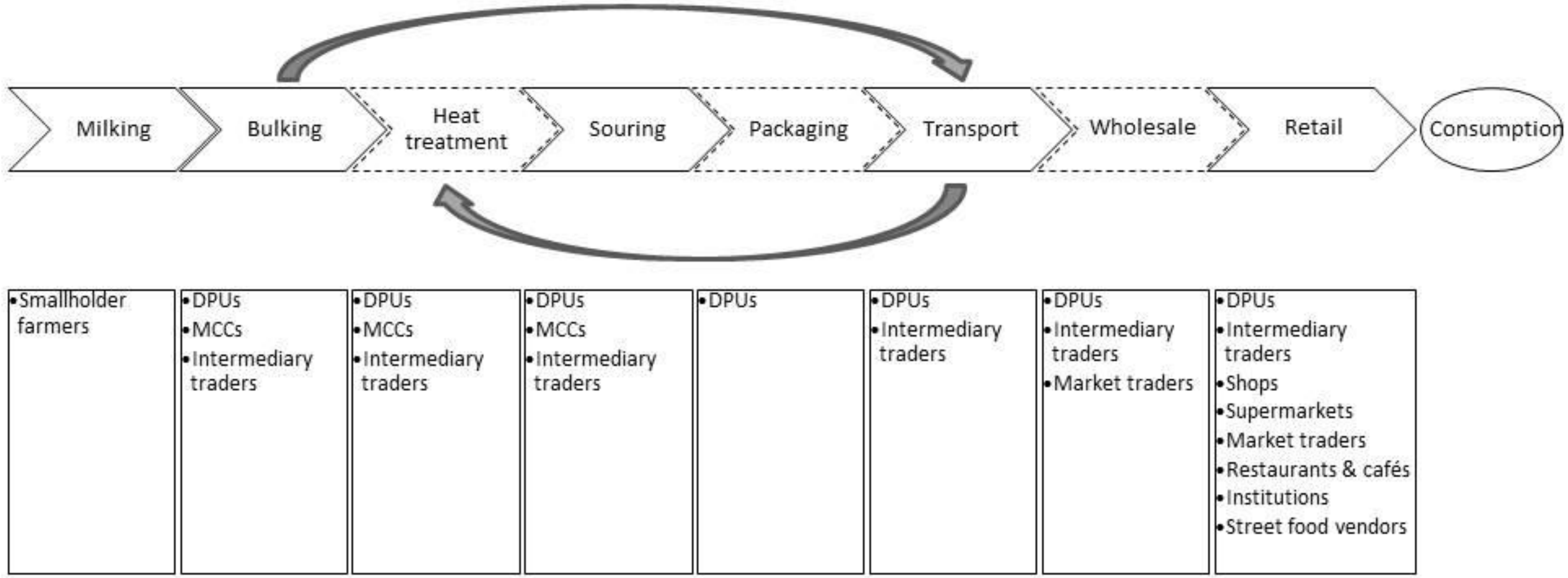


Figure 4-3 Milk value chain: urban-to-urban strand

The chevrons each represent a stage of the value chain where a particular process occurs. Where a chevron has a dotted line, the stage is optional and is not undertaken. The boxes underneath each chevron indicate which value chain nodes undertake this stage.

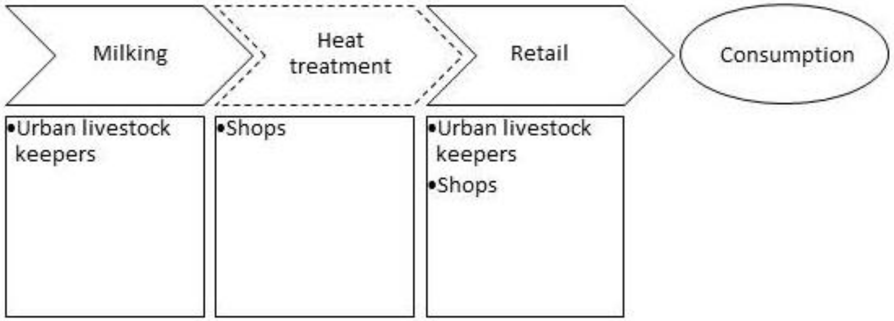


Figure 4-4 *Mtindi* value chain: urban-to-urban strand

The chevrons each represent a stage of the value chain where a particular process occurs. Where a chevron has a dotted line, the stage is optional and is not undertaken. The boxes underneath each chevron indicate which value chain nodes undertake this stage.

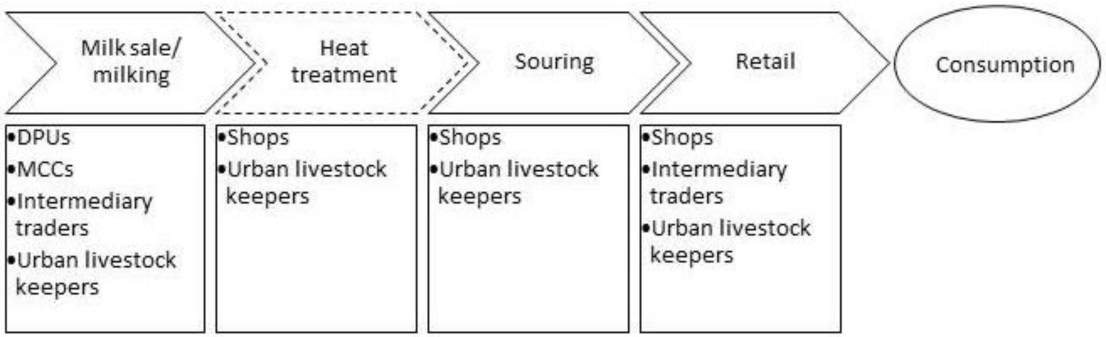


Figure 4-5 Milk and *mtindi* supply to Moshi Municipality: whole value chain overview

The background shading indicates whether the nodes were active in a rural (light grey) or urban (dark grey) location. The chevrons on the left indicate the stage of the value chain taking place. Each rectangular box represents a different value chain node. Each node is identified by its own colour. The direction of the arrow indicates the passing of a product (milk or mtindi) from one node to another. The various destinations of the products sold by a particular value chain node can be followed by tracing the arrows in the colour specific to that node.

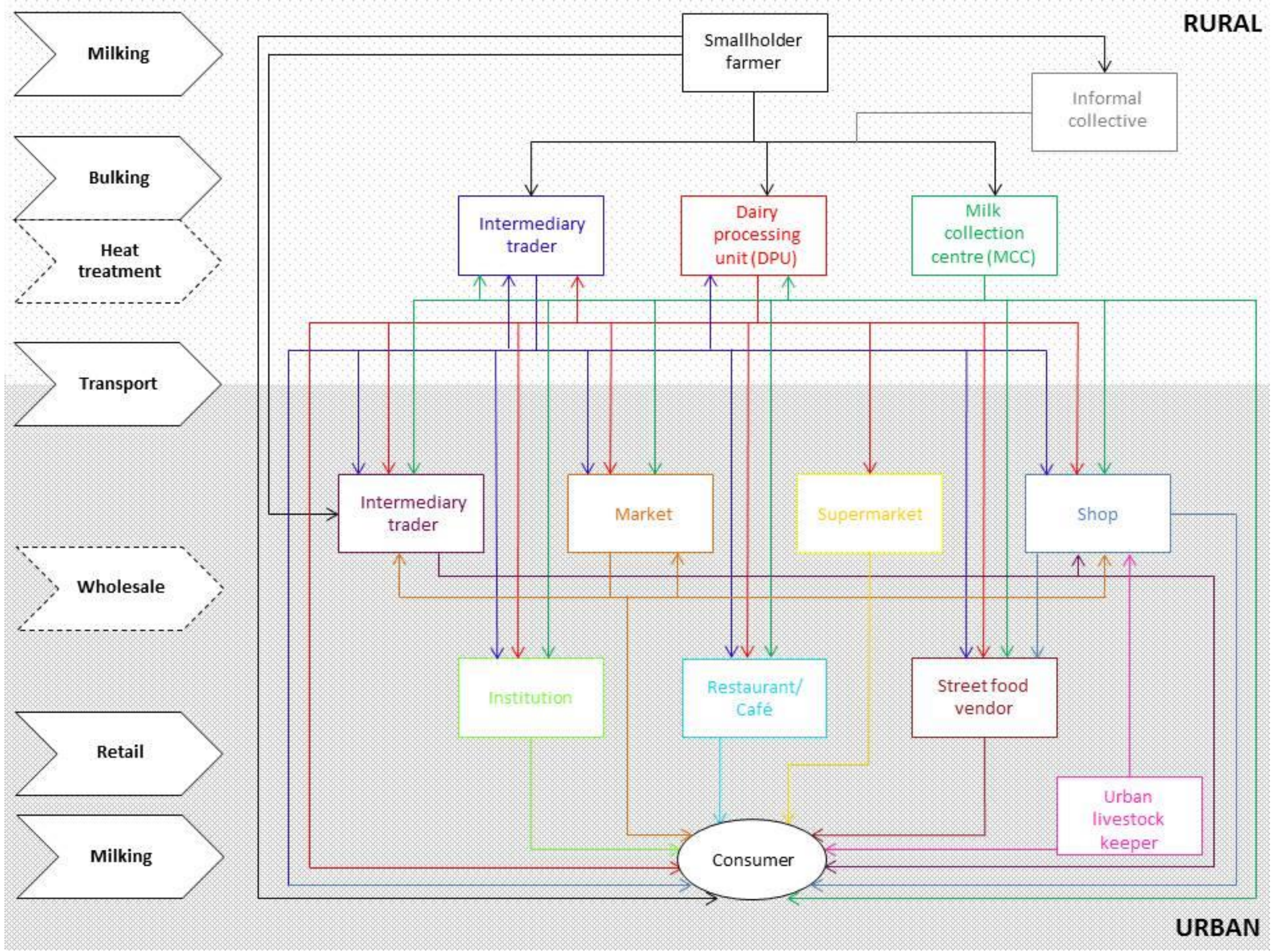


Table 4-2 Description of the value chain nodes and actors involved in the dairy value chains supplying consumers in Moshi Municipality

Value chain node	Description of characteristics
Smallholder farmers	All milk originating from Hai district was produced by smallholder farmers; there were no large dairies in the district. Smallholder farmers usually had one to three zero-grazed milking cattle, mainly crosses of an indigenous breed (Tanzanian Shorthorn Zebu) and dairy breed (Jersey, Ayrshire, and Friesian. This set-up is typical of dairy systems in Tanzania and East Africa more generally (Development Associates Ltd, 2009; Njombe et al, 2011; Otte & Chilonda, 2002). Dairy cow husbandry was overwhelmingly a female domain. Women were largely responsible for the daily milking, cleaning, feeding and general care of a household's dairy cows, as well as co-ordinating milk sales. Even when this work was delegated (e.g. to another household member or to a "cowboy", a young man employed to carry out activities related to cattle) the female head of household was usually responsible for ensuring the activities were executed smoothly and correctly. All of the smallholder farmers we interviewed had kept dairy cattle for decades and/or grown up in families keeping dairy cattle. All of the smallholder farmers we interviewed milked their cows twice a day (morning and evening) inside the cowshed, i.e. in the same location as the cows were housed.
Informal collective	While all of the smallholder farmers we interviewed sold their milk locally to nearby DPUs, MCCs or intermediary traders, smallholder farmers who lived in more remote or less accessible regions given the topography of the area (very hilly, poor roads, often very muddy after rains) reportedly found it difficult to travel to potential buyers for their milk; likewise, potential buyers often considered them too time-consuming to travel to. As a result, groups of farmers living in remote locations had reportedly set up informal collectives, whereby they employed somebody (usually male) to collect their milk together using his own transport (such as a motorbike or handcart) and deliver it to the purchaser.
Dairy Processing Units (DPUs)	At the time of research, there were two DPUs operational in Hai district, a further one that was under construction, and one that was operating as a milk collection centre (MCC) only as the Tanzania Food and Drugs Authority (TFDA) had ordered it to cease processing activities on food hygiene and safety grounds. Both active DPUs produced a range of products including processed (i.e. pasteurised) milk, *mtindi*, Western-style flavoured yoghourt, cheese, and butter. Milk and *mtindi* were by far the main products produced and sold. *Mtindi* was sold both packaged and unpackaged, whereas milk was almost always sold unpackaged. Other products were invariably packaged and sold to super-/mini-markets or institutions such as guest houses and tour companies, supplying primarily the expatriate, tourist and affluent Tanzanian markets. As is a common model in Tanzania, both DPUs were run by co-operatives that were initially set up with the help of external funds (Quaedackers, Linden and Boer, 2009) . Smallholder farmers paid a small fee for membership, which permitted participation in the management of the co-operative, as well as extra benefits such as access to loans, training seminars, or other input services such as animal feeds at competitive prices. Both active DPUs were women-only co-operatives. Each had a few hundred members, although not all members brought milk every day (e.g. if their cows were dry), and it was also possible for non-members to deliver milk to the plant. The plants collected milk seven days a week and processed it six days a week. There were twice daily milk collections in line with smallholders milking their cows twice daily. Processing took place throughout the day. Each DPU owned pick-up trucks which they used to transport dairy products into and around Moshi Municipality, leaving the plant at around 3-4am daily and arriving in Moshi Municipality around an hour later. Unpackaged products were transported in large (100 litre) and small (20 litre) plastic buckets, together with a smaller number of 100 litre metal milk churns.

Value chain node	Description of characteristics
Milk Collection Centres (MCCs)	MCCs existed as a point to collect milk from surrounding smallholder farmers to transport in bulk for onward sale. We identified 12 MCCs in operation in Hai district, and conducted fieldwork with five. Similarly to DPUs, all five MCCs were owned and run by co-operatives, two of which were female only. Again, non-members were permitted to deliver milk to the unit, but membership conferred similar benefits as to those described for the DPUs. The MCCs were small buildings based in villages, and could consist of only one room. All but one of the MCCs we visited had food-grade chiller tanks to combine, store and cool the milk collected to 4^0C. These MCCs opened twice daily at around 7.30am and 5.30pm in order to collect morning and evening milk from surrounding farmers, a process which usually took about an hour. The tank would be emptied of the chilled raw milk into buckets and churns in the very early hours of the morning (around 12am), and this milk taken into town for sale by pick-up truck in large plastic buckets and milk churns as for the DPUs. The MCC without a chiller tank had a different *modus operandi* reflecting its inability to store milk for long periods. This MCC opened earlier than the others at 5.30am, and sold its milk immediately to intermediary traders who then took it for sale in town that day. Evening milk was also collected at around 5.30pm and sold immediately to intermediary traders who were waiting with plastic buckets and jerry cans; however, in this case the traders would take it home and convert it into *mtindi* for sale at a later date.
Rural intermediary traders	Rural intermediary traders were unregistered, informal workers who collected milk from smallholders in their locality for onward sale in town as milk and/or *mtindi*. Milk could be sold boiled or raw; *mtindi* could be made from boiled or from raw milk. There were two broad groups of trader: those who owned a vehicle for transport, and those who did not. All of the non-vehicle owning traders whom we met during our research were female. Smallholder farmers would deliver milk to their homes after morning and evening milking each day, where it would be collected into plastic buckets and jerry cans. Shortly before dawn (around 5am) the traders travelled into town with their containers – a journey that would take an hour or more depending on weather conditions and where the trader lived. Most traders travelled by public transport, specifically a "*dala-dala*"[10] that was specially customised for this purpose (e.g. seats removed or raised to allow more space for buckets (Figure 4-15). The *dala-dala* took traders as far as Moshi Municipality bus station, from whence the women would take a second *dala-dala* to their regular trading location. While travelling by *dala-dala* was the most common option, we did meet a handful of traders who made other arrangements, e.g. paying for lifts with private vehicle owners. As these traders had no transport of their own, they had fixed trading points in town where they were known to sell milk. Of the six traders we interviewed who owned their own vehicle, all but one were male (this one female trader travelled in a pick-up belonging to her family, but hired a male driver). All of the male traders we interviewed bar one travelled by motorbike. As these traders had their own transport, they were able to collect milk directly from the farmers' homesteads, rather than the farmers having to go to them. They were also not restricted to selling milk at one particular place once in town, but could visit several common sales locations or deliver to customers direct to their door. If any milk was left over, they would convert this to *mtindi* to offset losses, but did not make *mtindi* regularly (unlike female traders who made *mtindi* to order).

[10] A *dala-dala* is a shared minibus taxi

Value chain node	Description of characteristics
Urban intermediary traders	Urban intermediary traders themselves resided in or nearby to Moshi Municipality, buying milk and *mtindi* wholesale from the various vendors arriving from rural areas and then selling it on in town. The urban intermediary traders served to distribute dairy products yet further from common sales locations to other residential areas. Having bought their products, they would set up a regular sales point at a specific known location each morning; sell the milk on to local shops; walk/cycle around the streets selling milk directly to householders; or a combination of the three.
Market traders	There was only one market selling dairy products in Moshi Municipality at the time of research: Kiboriloni market in Kiboriloni ward. This large open air market, covering ~6500m^2, took place on Wednesdays and Saturdays and was ~4km from the town centre. The majority of stalls sold fruit and vegetables, but there were also many stalls selling other products such as electrical goods, clothing, and household items. The market ran all day, with traders beginning to arrive around sunrise at 7am and trade continuing until sunset at 7pm. All of the dairy vendors were concentrated in one area of the market, and all were women. By far the main product they sold was unpackaged *mtindi*; it was very rare to see anyone selling milk. There were no fixed stalls; rather, vendors arranged themselves on the ground surrounded by their buckets. Around half of the vendors put up umbrellas or tarpaulin to shade themselves and their buckets from the sun, but others had no such shading. Bulk deliveries of *mtindi* began from around 8am, with most originating from Hai and Moshi Rural districts. Without exception, market traders reported that the majority of their customers were value chain actors buying wholesale who then sold it on themselves, although they were unsure what category they fell into (e.g. shopkeepers, urban intermediary traders, café owners etc). However, they also sold some *mtindi* directly to consumers at a higher retail price.
Urban livestock keepers	Key informant interviews with ward-level officials in Moshi Municipality revealed that, similarly to the rural smallholders, urban livestock keepers typically owned one to five cross-bred, zero grazed cattle that were kept in a cowshed adjacent to the house. Milking and husbandry was undertaken either by female members of the household or alternatively by “cowboys” specifically employed for the purpose, leaving the livestock owners free to do other activities such as paid employment in town. Owing to the small number of cows owned, urban livestock keepers produced small quantities of milk. Consequently this milk was usually sold directly to neighbours, in particular to families with young children. In rare cases where there was sufficient milk, urban livestock keepers might sell their milk to a shop in the vicinity. Although all four of the urban livestock keepers we interviewed sold only milk, the consumer survey revealed that some also produce *mtindi* for sale and are thus involved in the urban-to-urban strand of the *mtindi* value chain.
Shops	Every residential area in Moshi Municipality had a choice of small shops or kiosks, open from early morning till late in the evening, six or seven days a week. These retailers sold a wide variety of products including packaged food and drinks, and also other everyday items such as cleaning products, phone vouchers and stationery. Some shops that had an electricity supply would sell raw milk, which was stored in the fridge. Customers would bring their own containers to these shops and buy raw milk to take home. Any shop (regardless of electricity supply) might also sell hot boiled milk; in these cases, the milk was stored in a thermos and customers would buy a cup of milk to drink at the shop as a snack

Value chain node	Description of characteristics
	(the cups belonged to the shop and would be re-used). *Mtindi* was also sold in shops regardless of electricity supply, and consumed either at the shop or at home. This *mtindi* was either produced via the rural-to-urban value chain strand (i.e. produced in a rural area by DPUs/intermediary traders/MCCs and delivered ready to sell), or through the urban-to-urban strand, whereby intermediary traders/shopkeepers converted leftover milk that they were unable to sell into *mtindi* in order to minimise losses. Some shops also sold packaged *mtindi* and other dairy products, sourced from the local DPUs but also from DPUs elsewhere in Tanzania and imported (such as from Kenya).
Supermarkets	The only large Western-style supermarket in Moshi Municipality at the time of research was a branch of the Kenyan chain Nakumatt. There were also a few smaller minimarkets. These retailers generally served the more affluent Tanzanian and expatriate/tourist community, and were located centrally or in areas where tourists or expatriates reside. They stocked only packaged dairy products.
Institutions	Our research revealed that several institutions (including training academies, municipal offices, health centres) within Moshi Municipality took regular orders of the milk and *mtindi* originating from rural surrounds for use in their canteens or offices. Tour operators and guest accommodation for Western tourists also took orders of packaged dairy products; conversely, hotels and guest houses serving local populations were more likely to take orders of unpackaged milk and *mtindi*.
Restaurants and cafés	Often referred to by Tanzanians as "*hoteli*" ("hotels"), formal restaurants and cafés could be found across the town serving meals, snacks and drinks. These were permanent structures with a seated area, serving a wide variety of food and drink. As well as selling dairy products for consumption on the premises, some restaurants and cafes also sold milk and *mtindi* to consumers to take away for consumption at home.
Street food vendors ("*Mama Lishe*")	Literally meaning "Mother Who Feeds", *Mama Lishe* were informal, unregistered street food vendors, invariably women. Usually located at a roadside, they sold a small range of simple meals, snacks and drinks, such as various kinds of tea, hot milk, chapatti, or rice and beans, which they prepared in situ over a small fire. The activity has been identified as an important means for women to supplement the household income in Tanzania.(Milanzi, 2011)

Figure 4-6 Map of Hai dairy value chain nodes supplying Moshi Municipality

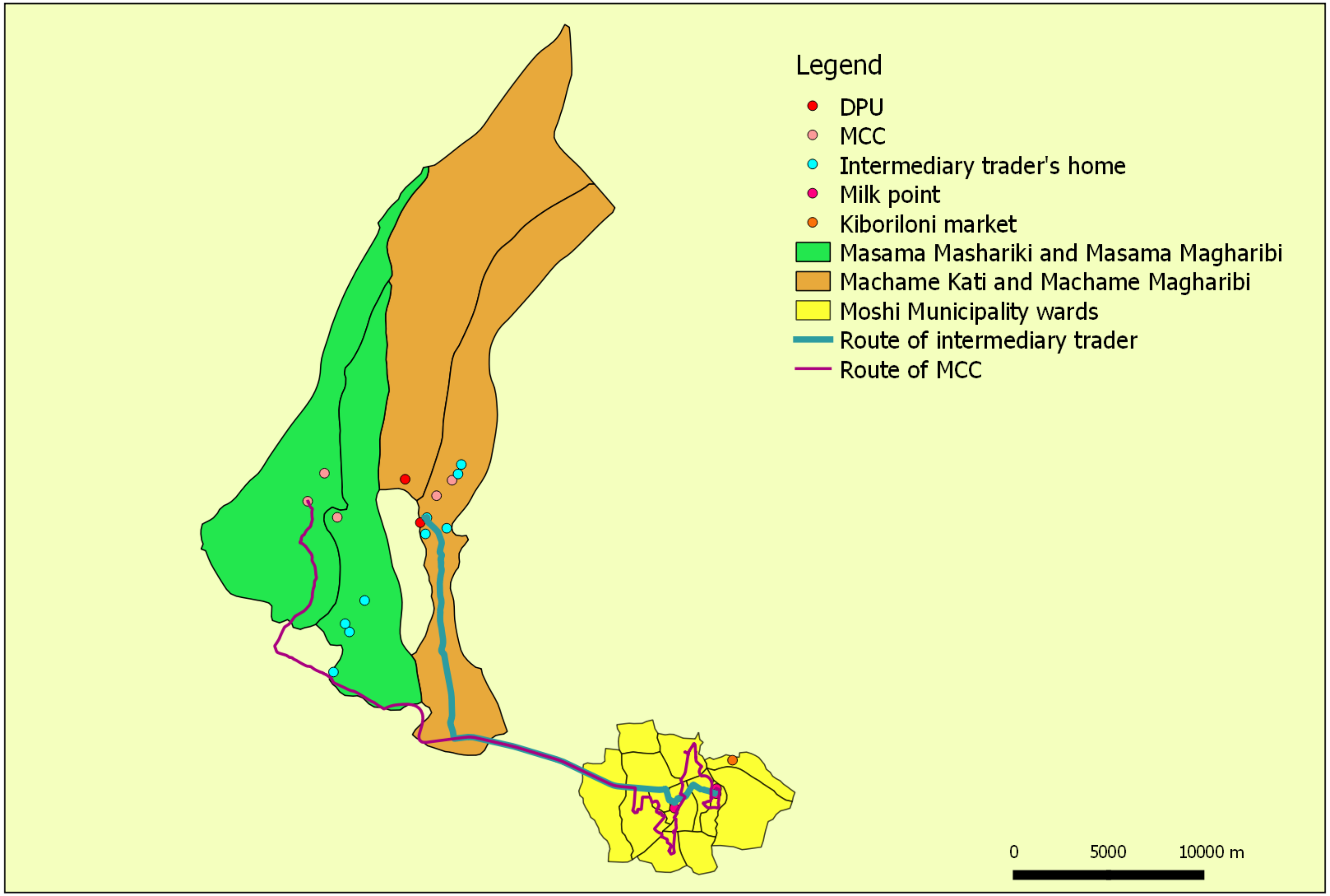


Figure 4-7 Cowshed in Wari village, Machame Kaskazini ward, Hai district.
The left hand door is the entrance to a food preparation area, a common set-up in the villages we worked in. The right hand door is the entrance to the cowshed.

Figure 4-8 Inside the cowshed, Wari village, Machame Kaskazini ward, Hai district

Figure 4-9 Farmer milking her cow in Foo village, Machame Kaskazini ward, Hai district

Figure 4-10 Smallholder farmers queue to deliver milk to a MCC in Moshi Rural district

Figure 4-11 Milk churns in the hot water tank, DPU, Hai district

Figure 4-12 Milk churns being transferred from the hot water tank (right) to cold water bath (left), DPU, Hai district

Figure 4-13 Emptying the chiller tank at a MCC in Hai district.
The milk is decanted into 100 litre plastic buckets ready to be transported into Moshi Municipality

Figure 4-14 Loading up products at a DPU prior to transport into town

Figure 4-15 Milk delivery *dala-dala*.
The front seats are removed to make room for buckets of milk and *mtindi*; the traders sit towards the back of the vehicle or in the front seat

Figure 4-16 Motorbike loaded with jerry cans of milk

Figure 4-17 Intermediary trader measuring out orders for her customers at her regular sales point, Mji Mpya ward, Moshi Municipality

Figure 4-18 Part of Kiboriloni market.
The dairy section can be seen on the left, and other stalls to the right.

Figure 4-19 The dairy section of Kiborilon market

Figure 4-20 A Kiborilon market trader measures out *mtindi* for a customer. The small red cup balanced on the green bucket in the foreground is used for tasting the *mtindi* prior to purchase.

Figure 4-21 Shop in Pasua ward, Moshi Municipality.
The text proclaims "*Tunauza vocha aina zote; Tunachaji simu aina zote; Maziwa fresh, mtindi na soda baridi*" – "We sell all kinds of phone voucher; we charge all kinds of phone; fresh milk, *mtindi* and cold soft drinks"

Figure 4-22 Mama Lishe street food vendor cooking chapatti and mandazi (Swahili doughnuts) in Miembeni ward, Moshi Municipality.
The large blue thermos contains *chai* - spiced milky tea.

4.5 Discussion of results

The research revealed two strands of both the milk and *mtindi* value chains: a rural-to-urban strand, in which the product (milk or *mtindi*) was produced in the rural areas surrounding Moshi Municipality and transported in for sale, and an urban-to-urban strand in which the milk or *mtindi* was produced in Moshi Municipality with the intention of sale in Moshi Municipality

Figure 4-3 to Figure 4-4 depict the sequential processes that occurred at each value chain stage, and the value chain nodes that were operational at each stage. The activities involved at each stage are described further in Table 4-1. In the rural-to-urban milk strand, the milk originated from cows owned by rural smallholder farmers whereas in the urban-to-urban strand, it originated locally from urban residents who owned cows. In the rural-to-urban *mtindi* strand, *mtindi* was made in rural areas either directly after milk was collected from smallholders, or from leftover milk that had been brought back unsold from town. *Mtindi* made directly could be made either through leaving raw milk to sour naturally, or by heat treating milk then adding a starter culture. Leftover milk would already have begun to sour by the time it was brought back from town, and would simply be left alone for the fermentation process to complete. *Mtindi* from the urban-to-urban strand could either be made by milk wholesalers/retailers from leftover unsold milk, or directly by urban livestock keepers. Converting leftover unsold milk into *mtindi* for sale was an important strategy to offset potential losses, particularly in times of high milk supply (e.g. during the rainy season) or low demand (e.g. during Ramadan).

Figure 4-5 gives an overview of the value chain nodes involved in the dairy value chains and how they were interlinked; Table 4-2 describes the characteristics of these nodes and of the actors participating at each node. We found that the milk and *mtindi* value chains largely involved the same set of actors, although the level of involvement differed. Despite the value chains being spatially relatively short, nonetheless a number of different nodes and actors were involved on the journey from “stable to table”. These actors were highly interlinked, and there could be several stages of transactional exchange before the final product reached the consumer. Each of these stages represented a potential point where infectious pathogens might be introduced (FAO 2011; Rich *et al.* 2011).

Figure 4-6 depicts the route travelled by a MCC and an intermediary trader as part of the rural-to-urban milk value chain strand. While Hai district is approximately 20km direct distance from Moshi Municipality, the actual distances dairy products travelled in this strand were much longer owing to the hilly topography in the rural areas, and to the additional distances vendors could travel within town if they had their own means of transport. Conversely, in the urban-to-urban milk value chain, urban livestock keepers produced small amounts of milk which they sold locally in their community.

The overall temporal length of the milk value chain strands was of necessity restricted by milk's propensity to spoil. The bulk of the milk brought in each day to Moshi Municipality from rural surrounds had been collected either the evening or the morning beforehand, although in a few cases may have been collected that morning if the value chain actor had suitable transport arrangements. Therefore, milk arriving in Moshi Municipality had originally been produced no longer than 24 hours beforehand. All of the shops we interviewed reported that milk could be stored for one day maximum, and any leftover the following day would be converted to *mtindi* as it would have begun to sour. The urban-to-urban milk value chain strand was even shorter; urban livestock keepers tended to sell their milk to customers (shops or residents) immediately after milking. In in-depth interviews and group discussions, almost all Moshi residents reported that they consumed milk on the same day as purchase, although two respondents who owned refrigerators reported storing it for two days/up to a week respectively.

The temporal length of the *mtindi* value chain was longer than that of milk, firstly because it took a minimum of 24 hours for the souring process to take place, and also because *mtindi* had a longer shelf life than fresh milk. Value chain actors who produced *mtindi* as part of the rural-to-urban value chain strand reported that they could store it for up to seven days at room temperature, although they were usually able to sell it before this time. Value chain actors who produced *mtindi* as part of the urban-to-urban value chain strand reported that this *mtindi* was usually sold within one to two days. Again, the vast majority of consumers reported that they consumed *mtindi* on the same day of purchase, although three reported storing it in the refrigerator for several days (up to two weeks in one case), and one for one day at room temperature.

For a number of reasons, it proved challenging to gather reliable data on the quantities of milk and *mtindi* flowing along the various value chain strands and how this was distributed amongst the various actors. Previous national statistics estimated that 90% of milk was estimated marketed informally, and only 2% processed (International Livestock Research Institute and East Africa Dairy Development/Tanzania Dairy Survey, 2012; TechnoServe, 2012). This picture is similar to that seen both elsewhere in Tanzania and in other countries in the East African region. For example, in Kenya, only 20% of milk is estimated to be marketed formally; in Uganda the estimate is 9% (TechnoServe Kenya, 2008; TechnoServe Uganda, 2008). Few official data were recorded in either Hai or Moshi Municipality districts that could be used to corroborate whether these national statistics applied locally. Many value chain actors were acting informally and thus unregistered, and unlike meat value chains which have natural points where livestock gather and their numbers can be recorded (e.g. at markets or slaughter slabs), there were no intervening stopping points in the milk and *mtindi* chains. Neither were accurate data available from the value chain actors themselves: most did not keep records of their customers and the quantities of milk/*mtindi* sold, and no value chain actor selling milk in town could give an accurate breakdown of the quantities and proportions of milk/*mtindi* they sold to shops, cafés, institutions etc.

Nonetheless, while difficult to provide quantitative estimates in the absence of data, there was broad consensus amongst participants that the rural-to-urban strands supplied a far higher quantity of both milk and *mtindi* than the urban-to-urban strands; that intermediary traders brought by far the most of the milk and *mtindi* produced rurally into Moshi Municipality, with MCCs following some way behind, then DPUs; and that in the urban-to-urban *mtindi* strand, most *mtindi* was made from leftover unsold milk rather than directly from fresh milk from urban livestock keepers. The consumer survey found that shops were the main outlets for buying both milk and *mtindi* (64.9% and 65.7% respectively), followed by itinerant milk vendors (which could be intermediary traders, DPUs, or MCCs) (26.9% and 20.9%), and urban livestock keepers (19.1% and 14.9%) (see Chapter 3 Table 3-10). Thus, in-keeping with national data, our findings suggest that only a small proportion of the milk and *mtindi* sold in town originated from registered processors, and informal actors dominated the value chains (Charles and Mchau, 2011; International Livestock Research Institute and East Africa Dairy Development/Tanzania Dairy Survey, 2012; TechnoServe, 2012). Unregistered intermediary traders proved to be a key resource linking customers in urban areas to smallholder farmer in rural areas. The integral role of this group of actors to the functioning of dairy value chains has been noted previously both in Tanzania and the wider region (Omore *et al.*, 2000, 2011; Omore, Arimi and Kang'ethe, 2002; Quaedackers, Linden and Boer, 2009). Any intervention or policy aimed at improving food safety along dairy value chains must thus have these actors first and foremost in mind.

A high degree of crossover between formal and informal dairy value chains has been identified as a common theme elsewhere in Tanzania as well as in a review of the dairy trade in five East African Community countries (Burundi, Kenya, Rwanda, Tanzania, and Uganda) (Development Associates Ltd, 2009; Alexopoulou K, 2011; Msuya, 2012). We too found that the distinction between the formal and informal sectors was blurred. If "formal" is interpreted as registered and known to the local authorities, then DPUs, MCCs, shops, restaurants, cafes and institutions could all be considered as part of the "formal" sector. However, the formal sector supplied the informal sector (e.g. DPUs selling to market traders or urban intermediary traders), and vice versa (e.g. rural intermediary traders supplying urban shops). The level of interplay between the two sectors suggests that while it might be expected that formalisation would reduce consumer disease risk, in reality the effects of formalisation may be limited.

Many of the activities that would foster the introduction and/or propagation of pathogens in the dairy value chains were undertaken both by formally and informally registered actors. For example, both intermediary traders and DPUs/MCCs primarily transported unpackaged milk in large plastic buckets that were not food-grade and were difficult to clean, in vehicles that were exposed to the elements. Neither formal nor informal actors used any kind of cold chain during transport or wholesale, with the result that milk and *mtindi* could be left out in the sunshine for several hours before sale, promoting bacterial growth (Figure 4-19). Where chilling facilities were available, e.g. at DPUs or in shops, these were nonetheless unreliable owing to frequent power cuts. Although some value chain actors had back-up generators, this was not always the case; for example, at one DPU staff explained that in the case of a power cut, they had to choose between running the refrigerators or lighting the plant as the generator did not produce sufficient energy for both. On the other hand, we also found that activities that would prevent the introduction and/or propagation of pathogens into the chains were undertaken by informal as well as formal actors. Heat treatment was not exclusively the domain of DPUs, for example. Rural intermediary traders who did not have access to refrigerators in their homes (approximately half of those we interviewed) would boil milk in large pans after collecting it from farmers to ensure it did not spoil before sale. The Codex Alimentarius Standard for Milk and Milk Products advises that minimum pasteurisation conditions require heating every particle of the milk being treated to 72^{o}C for 15 seconds or to 63^{o}C for 30 minutes (WHO & FAO 2011). Heat treating milk until it is visibly boiling, as was undertaken by the intermediary traders, would be adequate to ensure pasteurisation. Furthermore, the heat treatment method used by DPUs were basic. Milk was collected into large stainless steel churns which were individually submerged in a tank of boiling water heated by firewood (Figure 4-11). Each churn would be kept in the tank until it reached 90^{0}C, measured by dipping a thermometer into the top of the churn. After two to five minutes at this temperature, the churn would be removed and placed into a cold water bath until it reached ambient temperature, which usually took over an hour (Figure 4-12). These kinds of methods have been shown to be insufficient to pasteurise milk, with slow cooling providing an environment that promoted microbe growth (Ndungu *et al.*, 2016). It is thus possible that on some occasions, the efforts taken by informal intermediary traders to boil their small amounts of milk to prevent spoilage was more effective in killing microbes than a DPU's efforts to pasteurise large quantities of milk in bulk.

4.6 Conclusions

Our research revealed that both the milk and *mtindi* value chains comprised rural-to-urban and urban-to-urban strands involving multiple linked value chain actors and a large degree of overlap between the informal and formal sectors both in terms of actors involved but also in terms of potential infectious disease risk-driving and risk-mitigating practices. Each distinct strand of the milk and *mtindi* value chains potentially posed different disease risks to consumers as they represented different risk pathways through which milk/*mtindi* could become contaminated. For example, the urban-to-urban milk strand was very short both temporally and spatially and involved very few actors: usually, an urban livestock keeper selling milk immediately after milking to neighbouring householders who would consume it that day. Conversely, the rural-to-urban milk strand was far longer both spatially and temporally and could involve many different actors and exchanges before the milk finally arrived at the household for consumption. It could be expected that there were far more opportunities for milk in the rural-to-urban strand to be contaminated with infectious pathogens and for those pathogens to propagate, posing higher risks to the consumer than the urban-to-urban strand – even if the milk being purchased had been heat treated further upstream the chain, such as at a DPU. This is of concern given that the milk from the rural-to-urban strand dominates the supply of milk to Moshi Municipality, and is likely to become more dominant as the town grows and space to keep livestock becomes more difficult to find. However, the practice of boiling milk before consumption is widespread and is an effective strategy to mitigate the potential infectious disease risks posed by milk, regardless of its origin.

In the *mtindi* value chain strand – which to my knowledge is the first value chain analysis ever undertaken for this product – we found that the same actors were involved as in the milk value chain, with the addition of market traders. The rural-to-urban strand also predominated here, but the urban-to-urban strand, which mainly consisted of *mtindi* produced in Moshi Municipality from leftover unsold milk, proved an important means of offsetting losses, particularly in times of high supply of or low demand for milk. Almost exclusively, this leftover milk had been brought in to the town via the rural-to-urban milk strand (it was rare for urban livestock keepers to have leftover milk as they produced small amounts and their customers were generally known to them in advance). Most milk used to make *mtindi* in the urban-to-urban strand had therefore likely been subject to bacterial contamination and propagation en route to the town, exacerbated by a period of several hours in town at ambient temperatures in unhygienic conditions while the value chain actors attempted to sell it. However, while in the milk chains, consumers could be expected to know whether the milk they were consuming originated from the rural-to-urban or urban-to-urban strand (as sales were usually direct from an urban livestock keeper), consumers of *mtindi* would not be able to distinguish whether the product they bought originated from the rural-to-urban or urban-to-urban strand. Likewise, they would not be able to distinguish whether the *mtindi* they bought was originally made from boiled milk or from raw milk, which could potentially pose different risks. Moreover, while consumers could mitigate the infectious disease risks posed by milk by boiling before consumption, they could take no such measures for *mtindi* which is consumed as bought with no prior preparation. The structure of the *mtindi* value chains therefore places consumers in a heightened position of vulnerability to food-borne infectious disease risks compared to those posed by milk value chains, despite the similarity of the value chain actors, process, and geographies involved.

5 Function of the principal dairy value chains serving Moshi Municipality

5.1 Summary

Understanding how food-borne disease (FBD) risks arise in an animal source product (ASP) value chain requires understanding the wider socio-economic, cultural and political environment that underpin chain function and serve to drive or prevent risky behaviours. The current legislative framework regulating milk and *mtindi* ignores the context on the ground, reduces the competitiveness of formal processors through over-regulation, and fosters an environment where unregulated informal actors can thrive irrespective of potential food safety issues. In the absence of formal regulation, most value chain governance is channelled through internal systems built on social capital, trust, community engagement, belief systems and sanctions. These systems could either encourage food safety if value chain actors sought to preserve good relations with other actors by ensuring hygienic, high quality products; or jeopardise food safety if value chain actors placed the maintenance of a relationship over concerns for product quality and safety. Non-human actants such as the products themselves; ecological features; infrastructure; and materials and equipment also exerted a high degree of control over the chain and limited the degree to which actors could implement food safety measures. Profitability was precarious and could encourage value chain actors to engage in behaviours that could increase disease risk, such as converting leftover milk to *mtindi*; however, milk/*mtindi* pricing did not indicate that consumers preferred products that were potentially safer e.g. made from processed or fresh milk. Value chain actors had little by way of formal education in milk hygiene and handling; knowledge was primarily dissipated through social networks, allowing for undesirable practices to perpetuate within the chain. The milk/*mtindi* value chains adapted quickly to short-term changes such as in supply and demand, with food safety risks likely modifying alongside those changes. Longer term the changes are less clear: a lengthening of rural-to-urban value chains as the town expands may increase consumer risk; while nascent plans to develop a large processing unit outside Moshi Municipality could diminish consumer risk considerably.

5.2 Introduction

The approach to date to investigating FBD risk along dairy value chains has been to use information regarding value chain structure to identify nodes and actors along the value chain, take samples of milk and (rarely) *mtindi* at those points, and undertake microbiological tests for the specific organism(s) under investigation (Omore, Arimi and Kang'ethe, 2002; Hempen *et al.*, 2004; Arimi *et al.*, 2005; Yilma and Faye, 2006; Grimaud, Sserunjogi and Grillet, 2007; Millogo *et al.*, 2010; Bankole, Secka and Ly, 2011; Schooman, Swai and Daborn, 2012; Shija, 2013; Lubote, Shahada and Matemu, 2014; Yigrem and Welearegay, 2015; Doyle *et al.*, 2015; Joseph, 2015; Knight-Jones *et al.*, 2016). While this approach may indicate what and where pathogenic hazards occur along a chain, it does not address why these hazards came to be present, nor how they might evolve to pose a risk to the consumer. Identifying the presence of a hazard is not sufficient to make inferences about risk. Rather, understanding risk requires understanding the wider socio-economic, cultural and political drivers for behaviours that influence risk (Food and Agriculture Organization, 2011). Risk often arises as a result of the behaviours of value chain actors. In order to understand disease transmission, it is necessary to characterise not only these behaviours but also the motivations that lie behind them, recognising that risk is not driven by pathogens alone, but also by people (Rushton, Pinto and Taylor, 2009). The conceptual framework for value chain analysis that I presented in Chapter 2 (Figure 2-1) attempts to address this by broadening out from value chain structure to also focus on value chain function. Through examining governance mechanisms, economics, and knowledge flows along value chains, as well as how chains shift and adapt according to changing circumstances and the role that non-human actants play, the framework fosters the collection of those rich and diverse contextual data that are necessary to make informed evaluations regarding disease risk and drivers of risk along the chains.

There are few peer reviewed, published value chain analyses of dairy value chains in East Africa. The dairy value chain analyses available from Tanzania are primarily technical reports from development agencies or governmental bodies, and less commonly Masters theses (Alexopoulou 2011; Charles & Mchau 2011; Fussi 2010; International Livestock Research Institute & East Africa Dairy Development/Tanzania Dairy Survey 2012; Kifaro 2010; Mchau et al. 2009; Msuya

2012; Njombe et al. 2011; Quaedackers et al. 2009; Scanagari and Business Care 2006). These publications tend to concentrate on value chain structure, i.e. the nodes, actors, quantities, and geographies involved, and to a lesser extent on governance or economics. It is rare to find a detailed characterisation of a dairy value chain. An exception to this is a report from the development agency Technoserve (2012); however, while this report describes both value chain structure and function, it does not consider how these findings relate to disease risk. In this chapter, I present a detailed description of how the milk and *mtindi* value chains supplying Moshi Municipality function, the factors lying behind why they function in this way, and how this context might serve to drive or prevent infectious disease risk to dairy consumers. I begin with a brief overview of the methods used for value chain analysis, and go on to present and discuss results pertaining to specific value chain dimensions (governance, economics, knowledge and adaptation), before drawing all these results together in the conclusion.

5.3 Methods

We purposively selected 56 value chain actors participating in the milk and *mtindi* value chains nodes supplying Moshi Municipality: thirteen rural smallholder farmers, two dairy processing units (DPUs), five milk collection centres (MCCs), fourteen intermediary traders, eight market traders, ten shops and four urban livestock keepers to the study. We gathered data concerning the milk and *mtindi* value chains from these actors through a combination of in-depth interviews, participant observation, surveys, and time use surveys. We also gathered data through key informant interviews (KII) with representatives from the Tanzania Food and Drugs Authority (TFDA), Tanzania Dairy Board (TDB), Land O' Lakes Dairy co-operative, and local-, ward- and district-level government officials in the study area, and through in-depth interviews, group discussions, proportional piling exercises and a survey with residents of Moshi Municipality. I conducted a thematic analysis of the qualitative data using seven value chain dimensions (input-output structure, geography, non-human actants, governance, economics, knowledge, and adaptation) as etic codes and generating emic codes deductively while cycling through the data, using NVivo software to aid analysis (QSR International Pty Ltd, 2012). I analysed time use data in Excel (Microsoft, 2010). Further details of these methods can be found in

Chapter 4. As consumers are also part of the value chain, I also used findings from the research with consumers described in Chapter 3 to contribute to the value chain analysis.

5.4 Governance

I identified three broad forms of governance shaping the structure and function of the milk and *mtindi* value chains: external governance; internal governance; and governance by non-human actants. External governance refers to the official structures in place, which regulate and facilitate value chain function, i.e. legislation and policy, regulations and standards, and the governmental structures and institutions that implement them. It also includes donor organisations that contribute to the value chains. Internal governance refers to the ways in which interactions between value chain actor groups serve to organise the chain. Non-human actant governance refers to non-human objects and entities that exert control on how value chain actors can behave in the chain. I will describe each of these forms of governance in turn, highlighting the potential impacts on disease risk.

5.4.1 External governance

As a hangover from the top-down reorganisations of the dairy industry in Tanzania over several decades (nationalisation in the late 1960s followed by liberalization of the economy and collapse of the industry in the 1980s and 1990s), the legislative and regulatory environment governing the dairy trade in Tanzania is complex. A review by Charles and Mchau (2011) found no less than twenty laws covering some form of dairy value chain governance[11]. The principal two laws are the Dairy Industry Act of 2004 and its Regulations of 2007, and the Tanzania Food, Drugs and Cosmetics Act of 2003 and its Regulations of 2006. The Dairy Industry Act is the only piece of legislation that exclusively addresses the

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[11] i) Dairy Industry Act, 2004; ii) The Veterinary Act, 2003 ; iii) Business Activities Registration Act,2007 iv) The Standard Act,2009; iv) Special Economic Zone Act,2006; v) Tanzania Food, Drugs and Cosmetics Act,2003; vi) The Public Health Act,2009; vii) Tanzania Trade Development Authority Act,2009; vii) Employment and Labour Institutions Act,2004; vii) Labour institution Act, 2004; viii) Occupational Safety and Health Act,2003; ix) Business Registration and Trade License Act; x) Tanzania Revenue Authority Act; xi) National social security Fund Act,2002 xii) National Environmental Management Act, 2004 xiii) Town and Country Planning Act, 2002 xiv) Weight and Measures Act, 1982; xv) Local Government Act, 1982; xvi) Animal Disease Act, 2003 xvii) Fair Competition Act,2003 xix) The Executive Agency Act,1997; xx) Livestock Identification, Registration and Traceability Act, 2010.

dairy industry, and establishes within it the national Tanzania Dairy Board (TDB) as the primary regulator of the dairy industry. The mandate of the TDB includes: regulating dairy farms and other dairy enterprises; enforcing minimum quality and health standards for milk and milk products; coordinating other government agencies regulating the dairy industry and; strengthening dairy sector stakeholder organizations. The Tanzania Food, Drugs and Cosmetics Act of 2006 is concerned with regulations of food hygiene and safety.

These laws and their concomitant regulations are based on Codex Alimentarius (CA), the collection of internationally recognized standards, codes of practice, guidelines, and other recommendations developed by the Food and Agriculture Organization (FAO) and World Health Organization (WHO) in relation to foods, food production and food safety. The CA guidelines are stringent and serve as a "rule book" to facilitate fair international trade by ensuring that trading countries adhere to the same standards. However, basing domestic Tanzanian dairy legislation on these international standards is problematic, as the resulting regulatory framework ignores the actual context in which dairy value chains operate in Tanzania. The regulations exact strict criteria, which fail to acknowledge the local constraints to implementation, such as the dominance of the informal sector or deficiencies in infrastructure. For example, the Dairy Act stipulates that there should be no sale or distribution to the public of any milk for human consumption without it being pasteurised or otherwise treated to render it safe for human consumption; and that all milk vendors should be trained, certified and registered. The informal market, which represents as much as 90% of the milk sold in Tanzania, is left unacknowledged and thus completely unregulated, missing opportunities for context-appropriate food safety measures to be developed and implemented. In addition, the high standards set for registered dairy premises are difficult to achieve. This can lead to their failure, as we saw at one DPU which had been ordered to cease processing by the TFDA and was functioning solely as a MCC at the time of research:

> *The problem with the government is that they just set the rules at meetings, but they never see how things are on the ground. For example, they don't consider the new groups [new co-operatives who are becoming established], and they set rules that are very difficult to adhere to.*
> ***In depth interview at former DPU functioning as a MCC (DPU-03-014),18 June 2014***

In addition to being based on international standards, a second problem that I identified with the legislative framework was the high level of redundancy. There was much overlap between the mandates and roles of the institutions that were tasked with implementing them, as evidenced in the following exchanges:

> ***And what is the role of the Tanzanian Bureau of Standards [TBS] and how does that compare to what the TFDA does?***
> *Yeah, when you look in deeper, you find we are doing almost the same. Especially the food sector, how do you say, we are almost doing the same thing… Yeah – when you go into the actual practice, and if you ask even those people, I mean you will hear them say the same thing is done by TBS and TFDA… Although to our customers, that is a, I mean, it is something not very pleasant to them because there is another issue of revenue. Yeah, we have, I mean some areas there we cost them, we need them to pay. OK? And TBS is doing the same, so we find there is double payment of the issues when it comes to that area, it comes so bad for the people. Yeah. For example, we are licensing, we do like this for the premises, we have [inaudible] complying; it's mandatory, our law requires them to apply for registration where there's a fee to be paid. The same is done, and so the TBS also do the same.*
> **Key informant interview with a representative of the TFDA, 15 July 2014**

> *[The plant is licenced with] the TFDA, and the TBS. There are a lot of payments to make, e.g. taxes to the district itself, to TFDA, to TBS, TRA….*
> **In-depth interview at dairy processing unit (DPU-04-019), 24 June 2016**

This situation negatively impacted on formal dairy value chain actors, who found it difficult to navigate the complexity and adhere to the regulations, and who experienced high levels of taxation and levies from a number of different regulatory institutions thus decreasing their profitability. This finding is consistent with a report by Kifaro (2010) which identified six government institutions regulating milk production; five regulating milk transportation; four regulating milk vendors; and five regulating milk import and export. Kifaro's report demonstrated that these institutions often had responsibility for the same activity, creating a complex yet often redundant set of regulatory rules.

Nonetheless, despite the large number of institutions involved in regulating the dairy chain, we identified a complete lack of regulatory oversight with regard to Milk Collection Centres (MCCs). MCCs collected and mixed milk from scores of farmers, and distributed large volumes of this raw, mixed milk to potentially hundreds of consumers on a daily basis. Despite the MCCs each being registered and known to local authorities, they were not eligible for inspection or for milk testing under the current regulatory framework because they did not process the milk. TFDA and TBS were only tasked with regulating milk processors; there seemed to be a loophole in the legislation that because the milk collected by MCCs was not being transformed into “a product” (such as pasteurised milk, cheese, or yoghurt), on the premises, there was no need for TFDA or TBS to carry out inspections. Thus despite the potential disease risks that the bulked raw milk posed to consumers, MCCs eluded inspection entirely. This is of concern in light of the fact that government policy is to encourage formation of dairy co-operatives such as MCCs, suggesting they may become more numerous nationally in future (Ministry of Livestock and Fisheries Development, 2011).

Kifaro (2010) also noted that a lack of resources and staffing across the institutions responsible for the implementation of regulations was problematic, often leading to piecemeal and inconsistent implementation as a result. We heard several examples of this during fieldwork. For example, the co-operative leader of the DPU that had been ordered to halt processing reported that the main issue the TFDA gave for closure of the plant was the lack of a one way system (a biosecurity measure in which products and people inside the plant move in one direction only; this avoids cross-contamination between rooms). However, only one of the other two active DPUs we visited had a one-way system and this was not enforced in practice. Key informants in Moshi Municipality wards reported that shops selling milk should be regularly inspected, but there was no sense of agreement as to how often such inspections were or should be undertaken, by whom, or what form an inspection should take. One shopkeeper we interviewed had been trading without inspection for over two years. For value chain actors who were unregistered and acting wholly within the informal sector, the influence and impact of official legislation and

Table 5-1 Institutional roles in monitoring compliance with laws and regulations pertaining to the dairy industry in Tanzania (Kifaro, 2010)

Aspect inspected	**Institutions responsible**
Site inspection	Local Government Authorities National Environment Management Council Occupational Safety and Health Authority
Premises inspection	Tanzania Food and Drug Authority Local Government Authorities Tanzania Dairy Board Tanzania Bureau of Standards Occupational Safety and Health Authority
Vehicle inspection	Tanzania Dairy Board Tanzania Food and Drug Authority Local Government Authorities Ministry of Livestock Development and Fisheries
Health inspection of workers	Tanzania Dairy Board Tanzania Food and Drug Authority Occupational Safety and Health Authority Local Government Authorities Tanzania Bureau of Standards
Registration of factory and machinery	Ministry of Industry, Trade and Marketing Occupational Safety and Health Authority
Installation/inspection of factory/workplace	Tanzania Food and Drug Authority Occupational Safety and Health Authority Tanzania Bureau of Standards Tanzania Dairy Board
Fire inspection	Ministry of Home Affairs Ministry of Industry, Trade and Marketing
Product analysis and registration	Tanzania Food and Drug Authority Tanzania Bureau of Standards
Quality registration	Tanzania Food and Drug Authority Tanzania Bureau of Standards
Taxation and levying	Tanzania Revenue Authority Local Government Authorities Tanzania Dairy Board

regulations was largely reactive to the occurrence of outbreaks of infectious diseases, such as cholera or Rift Valley Fever. For example, vehicles bringing milk into the town might be stopped and inspected (further increasing the temporal length of the value chain) or individual traders might be temporarily required to seek permits to sell dairy products. However, such interventions were neither strategic nor co-ordinated, and for the most part informal value chain actors were left to conduct their business and determine their activities with very little input from regulating authorities.

Perhaps due to this inconsistent and unsystematic mode of implementation, there were hints of a lack of confidence in the regulating authorities on the part of value chain actors impacted by them. For example, one DPU had received a letter from the TBS informing them that the butter that they had tested had failed inspection owing to having excessive levels of coliforms, and that as a result, the DPU would be banned from selling the product unless they took corrective action. The letter was dated April 2014 but the inspection had taken place in November 2013. The DPU manager disputed the findings, saying that when the TBS came they had no cool box and took the butter to Dar es Salaam for testing in an unrefrigerated car, a journey of some eight hours. Moreover, she said the car contained many other non-food related products which could have caused contamination. The manager was adamant that the testing results were incorrect; however, having observed the packaging procedures for butter (done by hand, with no gloves, and with flies alighting on the packing table throughout the procedure), it was clear to me that contamination during production was a real possibility. The anecdote demonstrated that the research participant had little faith in the testing procedures and the regulatory authorities implementing them, and this lack of faith could be a barrier to implementing corrective action.

The overall consequence of the legislative and regulatory framework was to create an environment in which production of processed milk products was simultaneously over-regulated and ineffectively regulated, set against an informal sector which was in effect not regulated at all and MCCs which were registered and known to the local authorities yet eluded regulation. This reduced the competiveness of DPUs and fostered a market which favoured the sale of unprocessed milk compared to processed product which could be expected to be safer. Thus, as a consequence of is failure to recognise and respond to the national context, the legislative framework actually served to inhibit food safety rather than enhance it.

Aside from the official structures and policies in place to govern dairy value chains, a major actor in our study location was the United States-based commercial dairy co-operative, Land O' Lakes. The organisation has an International Development division, a non-profit organisation which aims to help farmers and enterprises in low-income nations to transform into profitable, business-minded entities (Land O' Lakes Inc., 2017). At the time of research, Land O' Lakes had been involved in various dairy development projects in Hai district and across Tanzania since 1999. Its most recent project, the Tanzanian Dairy Development Project, funded by the US Department of Agriculture (USDA), ran from 2010 and concluded during our fieldwork in June 2014. Land O' Lakes' stated project aims had been to create and strengthen dairy co-operatives; provide training and technical assistance to farmers and processors; improve supply of inputs; increase milk production and collection; improve dairy processing and quality assurance; develop market linkages; and enhance consumer research and marketing systems (Land O' Lakes Inc., undated). We found the organisation had a heavy influence in all of the four wards in Hai district in which we conducted fieldwork, supplying key support to the co-operatives running DPUs and MCCs in the form of consultancy expertise, training for staff and smallholders, and sourcing and funding assorted equipment from milk pails to processing machinery. While official Tanzanian governmental policy promoted the formation of farmer co-operatives, Land O' Lakes had played a fundamental role in facilitating the realisation of this policy in Hai district. Without the organisation's actions it is doubtful that so many DPUs and MCCs would have successfully been established and endured. Thus, at the time of fieldwork, Land O' Lakes could legitimately be considered as one of the most powerful actors governing the structure and function of the dairy value chains serving Moshi Municipality, and through its provision of training and food-grade equipment had almost certainly served to enhance the quality and safety of much of the milk supplied to Moshi Municipality. However, whether this was sustainable is questionable. Once the organisation's support had been removed and in the absence of an effective regulatory framework ensuring the safety of milk and milk products sold by dairy co-operatives, it was unclear what the long-term impacts on consumer disease risk would be.

5.4.2 Internal governance

> *There are no certification schemes; it's just that people have known the traders so long that they know it's OK to buy from them.*
> **Key informant interview, Njoro Moshi ward, 30 October 2013**

Internal governance of the milk and *mtindi* value chains was almost entirely mediated through what Putnam (1993, page 167) conceptualised as social capital: "the features of social organisation, such as trust, norms, and networks that can improve the efficiency of society by facilitating co-ordinated actions".

In reviewing the social capital literature, David and Li (2010) noted that these mechanisms of trust, social networks and norms facilitate co-operative trade through multiple means such as reducing uncertainty and transaction costs, discouraging opportunistic behaviour, fostering co-operation and increasing the efficiency of markets and organisations. For example, in a study investigating vegetable market chains for small farmers in China, Lu *et al.* (2008) found that having a high level of social capital had several positive impacts for smallholder farmers' buyer-seller relationships, including receiving better communication regarding market information, increased financial assistance, increased marketing power, and improved access to technical support, inputs and credits. As alluded to in the quotation above, I found that internal governance of the milk/*mtindi* value chains through social capital often served to fill the void of external governance through official legislation. This is by no means unprecedented; indeed, in a paper discussing the function of agricultural value chains in developing countries, Trienekens (2011) notes that in such contexts where integrated, official governance structures are absent, elements of social capital such as trust and reputation replace those absent structures.

Trust was fundamental to value chain governance: wherever possible, value chain actors would choose to do business only with actors whom they believed they could trust. Trust was mediated through various mechanisms. One mechanism was through close personal relationships such as family ties or friendships, as demonstrated in the quotation below:

> ***Why do you sell your milk/products to [this trader] in particular?***
> *Because it's not good to be an unreliable supplier. Alice is my dear sister*[12] *and my friend. Although there are many traders in the area, I started to sell to Alice and now I only sell there. When I started selling milk, there was a male trader who sold to town, but he stopped trading. Then I started to sell to a local shop, but when Alice started, because I know her I started to sell to her.*
> **In-depth interview with smallholder farmer FAR-02-012, 28 May 2014**

The role of familial, kinship or other close personal ties in governing value chains has been noted in previous studies (Rich et al, 2011; Serra, 2011; Trienekens,

[12] The interviewee was not actually related to the trader in question; the term *dada mpendwa* literally translates to "dear sister" but is commonly used in reference to close and trusted friends

2011). Another mechanism of engendering trust that has been noted in the literature is through experience-based knowledge (Zinn, 2008; Zischka, 2013). This certainly emerged as a theme in our research: along the length of the chains, value chain actors frequently reported buying products from, and/or selling products to, the same people every day. This would generate a proven history of, for example, supplying a good quality product or of timely payment, whilst at the same time allowing a personal relationship to emerge. These trusting relationships could act as a powerful incentive to produce high quality milk or *mtindi*. Cleanliness and hygiene and lack of adulteration were key attributes by which consumers rated dairy product quality, and value chain actors did not want to risk the relationships they had established by not fulfilling these expectations. Thus the need to maintain trust could incentivise behaviours that favoured food safety, for example by favouring good hygiene along the chain. However, not all food safety risks carried in milk are related to poor hygiene, and not all infectious pathogens in dairy products have short enough incubation periods that consumers would necessarily relate consumption of a product to feeling ill (see Chapter 1 Table 1-1). For example, *Brucella* organisms are passed from the cow to the milk, and symptoms of brucellosis may not occur for weeks or even months after consumption. Therefore, while these trust mechanisms may promote food safety, they are insufficient to ensure it.

Moreover, as the quotation below highlights, choosing to trust in itself could be risky:

> *As well as the [DPU] vehicle, we have three intermediary traders who come, buy maybe 40-60 litres, and sell in Moshi or to Buguni Merani… I'm a little bit worried about it, because we worry that these traders might take it, add water and would sell it on as [the DPU] milk. We wouldn't ever be able to know if they were doing that, and we wouldn't be able to discuss it with them as those people are still our customers, and we need to maintain a good relationship with our customers. But the intermediary traders make their market off the back of our name. They would say it was [the DPU] milk, so it could be bad for the reputation of [the DPU].*
> **In-depth interview with chair of DPU co-operative, DPU-02-007, 23 May 2014**

This anecdote highlights the risk inherent in a trust relationship, and the power imbalances that could ensue. The DPU Chair was worried that the traders she sold to might adulterate the milk and damage the reputation of the DPU;

however, she felt powerless to take action to mitigate this potential risk as she was concerned that doing so might damage the relationship she had built up with those traders. Similarly, an intermediary trader reported that she felt that she could not undertake any quality tests when farmers delivered their milk (e.g. smelling it, or using a lactometer to assess whether it had been adulterated or not) as it would undermine the trust that she had built up with her suppliers. In a paper exploring how individuals balance risk, worry and trust as ways to manage uncertainty, Alaszewski and Coxon (2009) use the example of safe sex, whereby a possible consequence of using explicit measures to protect oneself from sexually transmitted infections may undermine and damage an intimate relationship. In the milk and *mtindi* value chains supplying Moshi, value chain actors were sometimes reluctant to take explicit measures that could mitigate food safety risks in order not to damage the relationships they had formed with suppliers and clients. In this way, trust worked as a constraint to disease risk management.

Lack of trust was also a powerful reason not to enter into a relationship with a value chain actor, as exemplified in the following exchange:

> *At one point, the farmer asked Matayo why the government is only interested in helping groups and not interested in individual farmers and people. Matayo answered her that it's very difficult to reach everyone individually, that's why they insist on people organising into groups. He asked why they didn't consider joining [the DPU]. The women all joined in this discussion, and all had quite a suspicious and negative view of the group. They complained that the cooperative in truth only benefits three people: the chairperson, bursar and the secretary, and everyone else is exploited – that the leaders benefit more than the rest. Matayo said, how about you follow up with the co-operative leaders and find out how much profit they actually make? The women answered that it's not worth the effort because they would never give you the truth about the income and profit, and they would hide the reality from you so you think that you're benefitting.*
> **Field notes from discussions with smallholder farmers delivering milk to an intermediary trader, MOB-02-013, 28 May 2014**

The exchange highlights that the co-operatives were not universally seen as a "force for good" in the areas in which they operated, engendering feelings of distrust and suspicion amongst some community members. In her work with cotton farmer co-operatives in Mali, Serra (2011) demonstrated that community members do not all stand to gain equally from membership of a co-operative, and noted that benefits of group membership tended to be unequally spread as some members have more or better social ties than others. The smallholder farmers described above had recognised this phenomenon. This undermined their trust in the co-operative and drove them to prefer supplying to an intermediary trader whose business model they perceived as more transparent and fair. The anecdote highlights that while it may be expected that informal traders would be less trusted than their formal sector counterparts, this was not exclusively the case (although several farmers supplying MCCs and DPUs did cite lack of trust in intermediary traders as a reason not to supply milk to them).

Concern for the community also played a role in chain governance. This was particularly the case for co-operatives, where members would express a commitment to serve the community and provide markets for farmers living there, and pride in the community endeavour:

> ***Is the plant currently profitable?***
> *Yes, but we are making only a little bit of profit. Profit is not really the point, the point is to provide a stable market for farmers to sell their milk to.*
> [later on in the interview]
> *I'm proud that the plant is trusted. We have never disturbed any farmers, we have never delayed payments and we give loans. So it's a small plant, but we are managing it well.*
> **In depth interview at former DPU functioning as a MCC (DPU-03-014),18 June 2014**

Women's empowerment was also a topic that arose amongst the co-operatives, with the idea that supporting women farmers would extend wider benefit to children and families throughout the area:

> ***Why is it a women's co-operative?***
> *Normally in a family, it's the women who are more concerned with milk. The cows are owned by the men, but the milk is owned by the women. Also, the mother is more concerned with the children. The co-operative regulations are that none of the fathers are allowed here to pick up the money from the milk, as fathers would spend it on themselves whereas the woman would spend it on the family. So if the woman is empowered, then the whole family is empowered. In the beginning, co-ops were owned by men, for example KNCU [Kilimanjaro Native Co-operative Union, a coffee co-operative], but*

> *they went into decline. Women then took them over – the men said we would never succeed. But we did!*
> ***In-depth interview at DPU (DPU-04-019), 24 June 2014***

This sense of community engagement and responsibility thus meant that many value chain actors were strongly invested in the success of the enterprise. This could translate into the desire to produce good quality milk and *mtindi*, even if the endeavour was not particularly profitable. Again, this drive for a high quality product could translate into a higher degree of attention to hygiene and food safety.

Such feelings were not limited to co-operatives but were manifest at various points in the value chain. For example, two shopkeepers - one Christian, one Muslim - cited their religious beliefs as a reason for attempting to ensure that the safety of the dairy products that they marketed to their customers were safe to consume:

> ***If everybody adds water to milk why don't you add too?***
> *Is not good to add water, even the Bible says do not do bad things to others that you would not like to be done for you.*
> **Interview with shopkeeper, Mji Mpya ward, 29 November 2013**

Thus, belief systems could be a potential positive driver for food safety. However, this may not have been exclusively the case. For example, during one conversation with a staff member at an MCC that supplied a DPU, I asked what reasons there might be for a farmer to choose not to supply to the MCC. The staff member gestured at the long line of farmers waiting for their milk to be assessed. He replied that if a farmer had a large amount of milk to deliver each time, they may worry that other farmers in the community might see this and become jealous. The successful farmer would then be at risk of having a rival farmer cast a spell on her; because of this, that farmer might prefer to have her milk picked up by an intermediary trader in the privacy of her own home. In such a scenario, a belief system would be working against food safety as it discouraged farmers from delivering milk to be processed. Likewise, we identified certain social norms that potentially hindered food safety. For example, one trader explained that it was a cultural taboo in her village to smell food that was given to you. This constrained her from smelling the milk that was delivered to her as an organoleptic test to check for quality. Respecting social norms has been identified as vitally important to facilitating transactions and enhancing the co-operation between actors (Harriss and De Renzio, 1997; Lovell, 2009; Zischka, 2013). Therefore, while respecting social norms is essential for a value chain to function, doing so may potentially expose the value chain to disease risk.

The existence of sanctions has also been identified as key to ensuring mutually beneficial co-operation in an ongoing reciprocal relationship (Harriss and De Renzio, 1997; Zischka, 2013). I identified three types of sanctions imposed by potential buyers that reinforced the reciprocal agreements between value chain actors: rejection of the milk/*mtindi*; fines or temporary bans in supplying (usually preceded by up to three verbal warnings); and loss of future custom. These types of sanctions existed along the length of the chain, although fines and bans were more common at DPUs and MCCs, perhaps because they had a larger number of suppliers. Potential buyers could test the quality of the milk/*mtindi* through various methods such as organoleptic tests (checking smell, taste, visual inspection); using a lactometer to check the specific gravity of milk as a test for adulteration; the ethanol test, whereby milk and ethanol were mixed in equal quantities to assess whether the milk was too acidic (indicating souring, or the presence of colostrum or mastitic milk); and using the clot-on-boiling (COB) test, whereby a small amount of milk is boiled to see if it coagulates, which is also an indication of increased acidity (Food and Agriculture Organization and the & Ministry of Agricutlure, Livestock Devleopment and Marketing, undated).

The more technical tests were more commonly carried out upstream in the chain, particularly by DPUs/MCCs. For example, both DPUs whose milk collection process we observed used a lactometer to check all farmers, and both DPUs used the ethanol test at least occasionally (one at random on at least one day of the week, and the other as a follow-up test if the lactometer test was ambiguous). Four of the five MCCs used the lactometer at all times, and the remaining one used on all farmers on a random day once or twice a week. However, although nine of twelve intermediary traders reported using a lactometer, this was not necessarily the case in practice: two traders who indicated that they always used it did not use it at all when we later observed them collecting milk. This may reflect a reluctance in these more informal relationships to put the trust developed between two actors at risk, compared to the more formalised, contractual relationships between farmers and DPUs/MCCs which may allow for more objective tests. Further downstream the chain, technical tests were far less common: we did not identify any urban purchasers using the ethanol or lactometer tests. At this stage of the value chain, wholesalers and retailers tended to rely on organoleptic tests and/or feedback from their customers to ascertain whether the milk/*mtindi* they had been supplied with was of good quality.

In general, the desire to increase the certainty of sale was a major incentive for value chain actors along the length of the chain to ensure that the milk and *mtindi* they produced or purchased was of good quality; however, the competing incentive to maintain a good relationship with suppliers could also pose a barrier to both testing the quality of the product on purchased, and to sanctioning suppliers if quality was poor. Rather than imposing sanctions, we observed that value chain actors might instead use other measures such as letting the supplier off with a warning and mixing poor quality *mtindi* (e.g. bad smelling or visibly dirty) with good quality *mtindi*. Such measures would ensure that the purchaser still had sufficient *mtindi* for their needs (i.e. to fulfil customer orders), that the *mtindi* would sell, and that the relationship with their supplier was preserved; however these measures were clearly questionable in terms of food safety. Although a few consumers reported that retailers might refund milk/*mtindi* if consumers found it to be poor quality, this was always subject to the discretion of the retailer. Furthermore, although consumers were always free to change their supplier of milk/*mtindi*, the power of consumers was limited as it was sometimes difficult to find good quality dairy products from any of the retailers serving their locale.

5.4.3 Governance by non-human actants

We identified four broad groups of non-human actants that had a role in governing the value chain. The first group was the dairy products themselves. The perishability of milk and *mtindi* restricted the length of the value chains and also affected what value chain actors would sell it. The temporal length of the milk value chain was severely restricted by the fact that the product would sour after a number of hours; the *mtindi* value chain could be several days longer but was still restricted by eventual spoilage of the product. As FBD risk tends to increase the longer value chains become, arguably this perishability in itself served to mitigate risk somewhat. In addition, perishability acted as an incentive for value chain actors along the chain to handle the product hygienically. It also governed what value chain actors might deal in a product –for example, it was uncommon to find shops that did not have electricity selling milk, and rare to find any market traders selling milk. Furthermore, the properties of milk versus *mtindi* affected whether they were likely to be adulterated or not. As a liquid, it was comparatively easy to mix water with milk in order to increase the quantity for sale without the purchaser noticing (although we did not meet any value chain actors who admitted to the practice, many consumers complained that the milk they bought was adulterated in this way). However, *mtindi* is a textured, semi-solid product that would be difficult to adulterate without causing an obvious visible change in its appearance. Thus, the potential introduction of pathogens through mixing with unclean water was a problem for milk, but not for *mtindi*.

The second group was ecological features, comprising topography, season, and land use. These often worked in synergy with each other. The mountainous terrain of Hai district lengthened the milk and *mtindi* value chains both temporally and spatially. We heard anecdotes of some smallholder farmers walking up to 1.5 hours to a MCC to deliver their milk. Moreover, difficult terrain and topography could impede value chain actors' ability to form a relationship with each other in the first instance, dictating whether smallholder farmers could sell their milk to a DPU even if they wished to, for example. These difficult travelling conditions were exacerbated in the wet season, with muddy roads and poor visibility making travel times longer between all segments of the value chain, including those in urban locations, and increasing the risk of contamination as containers and vehicles became muddy. Some areas that were accessible in dry season would become less so in wet season, with the result that value chain geography, actor relationships, spatial and temporal length, could change according to season. In addition, season affected supply and demand, and consequently the amounts of products bought and sold along the chain. This could also affect value chain actor relationships, e.g. intermediary traders could reduce the number of smallholder farmers they bought milk from, which drove farmers to DPUs instead. Urban land use also drove demand for rural-to-urban dairy value chains, as dense populations and local regulations made livestock keeping difficult. Thus the shortest and potentially safest milk value chain – urban livestock keeper direct to consumer – was restricted in its availability to consumers.

The third group was infrastructure, comprising electricity, roads and water. Access to electricity by value chain actors at their locations of residence or sale was variable. This affected what products were sold, and also whether milk was boiled or not before sale. Even when there was access to electricity, power cuts could be frequent and were unpredictable in terms of both occurrence and duration. This would more negatively impact the milk value chain than the *mtindi* value chain as milk spoiled faster, but in both cases it could lead to economic losses, driving the practice to offset these by leaving soured milk to curdle further into *mtindi*. Road quality was almost always poor and worse in wet season, making milk and *mtindi* difficult to transport both on foot and by vehicle. This lengthened value chains temporally, offering increased opportunity for bacterial contamination. Moreover, in the absence of road surfacing, vehicles and containers became covered in dust (in dry season) or mud (in wet season), increasing the possibility of bacterial contamination of milk/*mtindi*. Finally, poor access to clean, free water inhibited value chain actors' ability to conduct their activities hygienically.

> *The Pare lady who is always making Matayo laugh, Mama D, was complaining about the water supply. When we came to her, she was cleaning an empty bucket with a dirty damp rag, and the water she was cleaning it with was grey. Matayo asked if he could help her clean her buckets and she said "Where is the water?!!". She said there is no water in Kiboriloni, because people in Kiboriloni had voted for a poor ruling party. So she used the little amount she had to clean the buckets with a quite dirty cloth, and the water was pretty filthy.*
> **Field notes, visit to Kiboriloni market, 7 May 2014.**

The fourth group was materials and machinery, comprising vehicles, containers, and processing/bulking equipment. Vehicles governed access to markets; for example, intermediary traders without their own transport could only sell at one specific point, whereas those with their own vehicle had the potential to find more customers. The type of vehicle also determined the amount a value chain actor could sell – for example, there was a physical limit to the amount of milk that could be carried on a motorbike which ultimately limited the number of consumers who would be put at risk by a motorbike trader selling contaminated milk. Similarly, container type governed what quantities of dairy product that a value chain actor could transport and sell. Straight sided buckets were easy to stack, while plastic jerry cans were easy to tie onto motorbikes and pick-up trucks. Metal milk churns possessed neither of these properties. Furthermore, plastic buckets and containers were ubiquitous in availability as they were used as containers for myriad everyday products such as paint, oil and foodstuffs. Their ubiquity also made them cheap. Food grade metal churns and buckets, however, were imported, not widely available, and expensive. Collectively, these container properties drove value chain actors to prefer collecting and transporting milk and *mtindi* in plastic containers rather than food-grade metal churns, even though these actors often recognised that metal containers were superior in terms of hygiene and food safety. Lastly, the milk processing/bulking equipment used in the area of study was imported and expensive, with value chain actors relying heavily on donor funding to gain access to them. Once in place, few in-country experts were available to maintain the machinery, which could sometimes render it defunct, and the methods used for processing were low-tech and inefficient (e.g. pasteurisation by boiling churns, and packaging products by hand). Thus the equipment available in Tanzania hindered the capacity to bulk and (in the case of DPUs) to process milk in the region. This created a gap in supply, fostering a favourable environment in which informal sale of raw milk and *mtindi* by intermediary traders could thrive.

5.5 Economics

Table 5-2 shows the range of prices that the value chain actors we interviewed sold their milk for along the length of the value chain (note that these are wholesale prices, except for shops and urban livestock keepers, who retailed direct to consumers). Prices within a village or town area were largely the same; the variation in price for each value chain actor group was largely due to price differences between villages or town area (e.g. shops in one ward all sold at around the same price, but shops in another ward sold at a different price).

As is apparent, DPUs and intermediary traders sold largely at the same price; there was little evidence from the pricing that consumers were willing to pay a higher price for a processed, potentially safer product. MCCs, which could bulk milk in large quantities and thus benefit from economies of scale without having any of the expense of processing milk, were able to undercut DPUs and intermediary traders and sell raw milk at the lowest prices. *Mtindi* was sold at either exactly the same price as milk, or at a slightly increased price (eg. 100 TSh/litre higher) which vendors explained was to reflect that the souring process entailed a reduction in quantity (as the whey that separated out during souring was discarded). There was no difference in price according to whether the *mtindi* was made of raw or boiled milk, and no difference according to whether it was made from fresh or leftover milk, again suggesting no consumer willingness to pay for a product that might potentially be safer, or alternatively a lack of awareness that one product might be safer than another.

Table 5-2 Range of prices at which milk is sold by value chain actor

Value chain actor group	**Range of prices at which milk is sold by value chain actor (per litre)**
Smallholder farmer	500-800 Tsh (£0.17-0.27)
MCC	650-800 TSh (£0.22-0.27)
DPU	800-1000 TSh (£0.27-2.34)
Intermediary trader	700-1000 TSh (£0.24-0.34)
Shop	1000-1200 TSh (£0.34-0.41)
Urban livestock keeper	1000-1200 TSh (£0.34-0.41)

The two DPUs reported low profits arising from high running costs due to the large amounts of water, electricity and firewood necessary for processing; the cost of processing and packaging equipment itself (which could sometimes be bought new several times as there was insufficient in-county expertise to maintain it); wage labour; and taxation and licencing by multiple institutions. While they wished to sell at higher prices to cover these costs, they were restricted from doing so owing to the competition from other actors selling unprocessed milk and *mtindi* – although they were be able to increase profitability somewhat by their ability to make a wider range of products to cater for different markets (e.g. the tourist market). In general, profitability was variable and precarious along the chains, and we encountered several behaviours undertaken by value chain actors that attempted to save costs or increase profits. Many of these potentially increased disease risk. Some of these have already been mentioned, such as the cost of water in Kiboriloni leading to poor cleaning practices by market traders, or the reportedly widespread practice of milk adulteration. The high cost of firewood was also quoted by intermediary traders and key informants alike as a disincentive for boiling milk for conversion to *mtindi*. Value chain actors were highly motivated to ensure they sold all of their products in order to maximise their income, which could incentivise good hygiene practices (e.g. cleaning vessels thoroughly) but also led to an unwillingness to discard unsold products. This drove the urban-to-urban strand of the *mtindi* value chain, where leftover milk which was potentially highly contaminated after hours of remaining unsold in often unhygienic conditions at high temperatures was converted to *mtindi* for sale and consumption rather than being discarded. As noted by van Tilburg *et al.* (2007), a key feature of tropical food chains is the existence of strategies to valorise poor quality or leftover products to minimise wastage and subsequent economic losses. Such strategies merit particular attention in relation to FBD.

In addition to the financial profits stemming from participation in the value chain, value chain actors described various non-monetary benefits. Smallholder farmers noted that milk provided a source of nutritious food for the family, and manure could be used to fertilise the household's agricultural land – one farmer even had a biogas system set up. Smallholder farmers who belonged to co-operatives could also access a range of additional benefits such as loans, payment of school fees or healthcare bills in exchange for milk, reduced-cost inputs such as feeds, stipends for attending co-operative meetings, access to training seminars, and reduced-cost food-grade milking equipment. Moreover, involvement with a co-operative could be a source of pride or empowerment. Given that participation in the milk and *mtindi* value chains generated wide-ranging benefits in both monetary and non-monetary terms, it should be noted that interventions to mitigate disease risk could potentially have far-reaching implications for the lives of the value chain actors working within them and the communities in which those value chain actors live.

5.6 Knowledge

Fieldwork uncovered four main sources through which knowledge was accessed and generated along the value chain: didactic sources, social networks, observation and experience, and technology.

"Didactic knowledge" was knowledge gleaned from experts by way of some method of formal instruction, and was largely limited to cattle owners, particularly smallholder farmers who were members of DPU/MCC co-operatives, and the staff at those co-operatives. Value chain actors operating solely within the informal sector (such as intermediary traders or market traders) had little access to didactic knowledge, unless they owned cattle themselves and could access it through this role. Livestock field officers (LFOs), employed by local government officials, were important sources of didactic knowledge for both rural smallholder farmers and urban livestock keepers. Access to LFOs seemed variable, but in general was facilitated via three routes: through home visits, (e.g. for artificial insemination or animal sickness); through their presence at churches or mosques (e.g. to announce an outbreak or vaccination programme); and through seminars organised by the ward, district, or DPUs/MCCs. DPUs and MCCs also arranged seminars for co-operative members given by representatives from the district office, Tengeru agricultural college in Arusha, the co-operative board or Land O' Lakes staff. Land O' Lakes also conducted visits to co-operative members' smallholdings so that farmers could learn "in situ". DPUs and MCCs also organised for a small number of co-operative members to visit Tengeru agricultural college for short dairy-related courses with the idea that these farmers could then return to feed back their knowledge to their peers.

However, despite these various avenues of didactic knowledge we found that the most important source of knowledge generation and transfer was overwhelmingly through value chain actors' social networks, again highlighting the importance of social capital to value chain function. This source of knowledge was key for all the different groups of value chain actors in the chains, but particularly so for informal actors who had no access to didactic programmes. The communication of information through social relations has been highlighted as one of the key ways in which social capital benefits individuals (Coleman, 1988; Harriss and De Renzio, 1997). Indeed, a recent paper from Uganda demonstrated that deliberately targeting social networks was a superior means of disrupting knowledge flows within rural communities compared to targeting formal community roles (such as health workers and village leaders), and suggested that in low-income countries, network-based approaches could be a powerful tool to interrupt transmission of information, behaviours or pathogens (Chami *et al.*, 2017). In our research, value chain actors made use of various social networks to access knowledge, including familial or kinship ties - it was common for smallholder farmers to report that they had learned milking and cattle husbandry through watching parents or other family members while growing up. The value chain itself proved an important social network through which knowledge was gained and transferred. We found examples of actors gaining knowledge from actors upstream from them in the chain (e.g. shopkeepers informing consumers that they should boil milk before consumption) and from downstream in the chain (e.g. feedback from intermediary traders to smallholder farmers regarding current milk pricing in town).

We also found horizontal knowledge transfer between value chain actors at the same node in the value chain to be very common, despite the fact that that these actors were in competition with each other. Where one might expect competitive relationships to be at arms' length, we found many demonstrations of trust and good relationships that fostered knowledge sharing between competitors. For example, at the market and at milk points, traders would often sit together in groups to sell their products. The traders explained that in doing so each would learn each other's practices and customers, with the benefit that in case of sickness or other emergencies, another member of the group could cover their business. The danger of not having such close social ties with other traders was highlighted by the predicament of young male intermediary trader who had not developed such linkages and was subsequently forced to get back to trading very soon after having a motorbike accident for fear of losing his customers. Finally, an emerging source of social capital was the recent setting up of national stakeholder associations, such as the Tanzania Milk Processors Association (TAMPA) and the Tanzania Milk Producers Association (TAMPRODA). These groups also represented fora for dairy processers and producers respectively through which these actors could meet and knowledge could be constructed and dissipated.

Value chain actors at all nodes also gave examples of how their knowledge could be generated by observation and experience. For example, they might watch other value chains actors' practices, or inspect milk, *mtindi* or actors' hygiene as a way of informing decisions as to who to trade with. Experience enabled value chain actors to hone their own practices, for example, knowing what quantities of milk/*mtindi* to bring to sell, or choosing not to purchase milk from a certain supplier because their product had been bad quality in the past. Lack of a negative experience also generated trust in other value chain actors and in the quality of the products they sold. Trust could then become a proxy for knowledge, e.g. with value chain actors feeling they did not need to check the milk or *mtindi* delivered by their usual suppliers as they knew it would be good quality. Lastly, technology had a limited role in generating knowledge in the value chain, most commonly generated at DPUs and to a lesser extent at MCCs (e.g. use of lactometers in milk collection or thermometers in heat treatment).

While knowledge could be acquired or created through several different sources in the value chain, I also identified several barriers to knowledge flow. These arose firstly because of the low requirement for specific skills or knowledge to enter the chain. Value chain actors would be able to sell their products without further training, so would not see a need for it, or indeed might be unaware that there were areas in which they might be able to acquire more skills (e.g. milk hygiene and handling):

> ***Who do you go to for advice or expertise on how to do this job well?***
> *Nobody, it's just me.*
> ***Have you ever had any formal training on how to get or sell good quality mtindi?***
> *No, never. I don't need any – there's no training that's necessary just to sell mtindi. If I had my own cows to milk then maybe I'd need training.*
> **In-depth interview with market trader VC28-MKT, 25 June 2014**

Thus some value chain actors felt a low motivation for learning and training as they were able to function effectively without it. The low profitability of the chain participation acted as a disincentive to learn more:

> ***Do you feel that there is sufficient training and information available for those working in the dairy industry to produce and deliver a safe product for consumers in Moshi town?***
> *The problem is that there are no factors encouraging them to produce safe milk, or even to seek information on how to produce safe milk. So they don't care: what I produce is what I produce, how I produce is that way. If someone doesn't want to buy, I will sell to someone else. So many people aren't informed, but part of the reason isn't because there is no information available, it's because they don't care. And the reason why they don't care is because they don't have an incentive for it – the price is poor, the market is a struggle, everything is hard. So you don't want to spend more time seeking information if you can't see the benefit of it.*
> **Key informant interview with the livestock field officer for Machame Kaskazini ward, discussing the farmers and traders involved in the dairy value chain, 13 May 2014**

Another barrier was time. The value chain actors we interviewed tended to have very long, full days with little time left over that could be dedicated to training or learning. There could be several competing activities alongside those associated with the dairy value chain – for example, other paid employment, agricultural activities or domestic duties. Related to this, the didactic training that was available could sometimes be offered to unsuitable participants. For example, Land O' Lakes organised a "Train the Trainer" farmer scheme which necessitated trainees to leave the home for two to three days. This time requirement ruled out the participation of most women, who were responsible for running the household – but as the people who were most likely to be involved in dairy activities, they were also most likely to benefit from training. One urban livestock keeper also complained that although the ward offered regular didactic training in husbandry and milk training, the turnover of the "cowboys" working for her was so high that it was not worth investing the time training them as they would soon leave.

Access to expertise could be problematic. The lack of in-country experts to advise on dairy processing techniques and equipment maintenance has already been described. The availability of LFOs to livestock keepers in the area was also questionable. It is well recognised that there is a national shortage of LFOs to serve farmers (Ministry of Livestock and Fisheries Development, 2011). Nonetheless, Hai district is better served than most; estimates in 2006 in the district were of one LFO serving approximately 470 households, around half the recommended workload of 800 farmers per officer (Scanagari and Business Care, 2006). In our fieldwork, smallholder farmers almost without exception reported that they felt their level of access to LFOs was acceptable. However, we found contrasting reports from the LFOs themselves, for example during this interview with an LFO in Machame Kaskazini ward:

> *Low motivation: the salary is VERY low, and there is no budget for transport, no allowance even for stationery to allow you to post announcements, no allowance for seminars. And the LFOs or VEOs*[13] *actually cause a big loss to the farmers themselves, e.g. if there are outbreaks of diseases, the farmer wants help but the LFOs have no transport so can't be there in time. Here there is no place for animal drugs, if there's an outbreak you have to go yourself and buy drugs from town and you sell them at a price that's comfortable for you, but may be expensive for the farmers. Seminars for the LFOs are at district ward offices, not at the village themselves, and they don't even provide bus fare or lunch or even chai. Even if you submit a report to the district office and they find some errors, they will call you to come to the district office to correct it, and you have to pay for yourself – meals, transport, whatever! So the LFOs and VEOs are very demotivated, they can't even feel like helping the farmers because they are so demotivated.*
> **Key informant interview, Machame Kaskazini ward office, 13 May 2014**

In addition, the training that LFOs received was not standardised, and different LFOs specialised in different areas. This could mean that even if a LFO was available, they might not have specialist knowledge in dairy cattle as they may not have been trained in cattle husbandry or milk quality assurance. Land O' Lakes played a critical role in filling the gaps left by the official local governmental authorities, and much of the training received by farmers working in our field villages derived from this organisation. However, none of the co-operatives had firm plans in place with regards how training would be continued in the absence of the organisation after the project came to an end.

Other barriers to knowledge flow included limited financial capital. Putting on or participating in training seminars, and buying technical equipment such as lactometers all cost money. One DPU board member also identified the limits of their social capital as a barrier to knowledge flow. She noted that board members were simply selected from the village, and they therefore had few

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[13] Village extension officers – one grade below the LFOs, VEOs are responsible for assuring services to village level (LFOs are responsible for ward level)

external links that they could exploit to encourage knowledge sharing. She also complained that as the plant was small it was sometimes forgotten when it came to state-organised dairy training activities. Finally, value chain actors noted that even if they had specific knowledge, they may not have any power to ensure it could be acted upon. For example, intermediary traders might know that if farmers mixed morning with evening milk it would be likely to spoil before sale, but it could be hard to ascertain whether they had done so when they came to deliver it. Similarly, market traders would have few ways of knowing if the *mtindi* they received was good quality, and no way to know how their customers stored or handled the *mtindi* once they have sold it. Therefore they had a lack of agency to ensure that the knowledge that they did have about dairy hygiene was implemented. This could act as a disincentive to act upon this knowledge at their own point of the chain.

In summary, the mechanisms of knowledge flow along the milk and *mtindi* value chains may have served to exacerbate the risk of introducing or propagating harmful pathogens within the chains. Formal training on milk handling and hygiene was relatively sparse and largely limited to upstream in the chain, i.e. smallholders, DPUs and MCCs, while other value chain actors eluded training entirely. Moreover, it was simple for actors to participate in the chain in the absence of any formal training specific to milk. The strong social networks that were crucial to the functioning of the value chain function were of key importance to facilitate knowledge transfer; while on the one hand this could mean that good practice learned upstream in the chain could potentially percolate further down, it also meant that knowledge and behaviours that could introduce disease hazards could perpetuate within the chain unchallenged, particularly in the face of the many barriers to knowledge advancement that were identified.

5.7 Adaptation

Most of the short-term adaptations in the dairy value chains (e.g. changes in supply and demand owing to season or religious events) have been described in this and the previous chapter. However, our fieldwork did indicate some longer term changes that were shaping how the chains were structured and how they operated which may have implications for disease risk. The rapid pace of urbanisation within Moshi increased local demand while at the same time reducing local supply, as residential housing became more congested and municipal regulations placed restrictions on livestock keeping in highly populated areas:

> *I used to own six cows five years ago, and I had to give them up because there is no space. So I think other people would also have to have given up their business in keeping livestock…The government has contributed to this problem because it's failed to arrange the infrastructure for citizens properly, hence people migrate from rural areas to town seeking quality services but they end up living in very, very small spaces where there is not enough space to keep animals...Generally migration of people to town is among the factors contributing in changing the whole system of milk supply.*
> **In-depth interview with consumer, Longuo ward, Moshi Municipality, 15 November 2013**

Thus, urbanisation was driving the demand for milk to be produced outside of Moshi Municipality and transported in. This implies a lengthening of dairy value chains which would imply an increasing disease risk to consumers. However, at the same time, in recent decades there has been a shift for rural farmers to raise dairy cattle for commercial gain rather than purely for subsistence. Rather than the traditional system of grazing indigenous breeds, which are hardy but low-producing, government policy has promoted artificial insemination, improved breeds, and zero grazing over several years (Ministry of Livestock and Fisheries Development, 2011). The fruits of these policy drives were very evident in Hai district; all of the cattle kept by the smallholder farmers who participated in the research were improved breeds, and almost all were zero-grazed. In addition, Hai district key informants explained that there had been a move away from producing coffee as a means of generating income in towards milk production instead, owing to the proliferation of coffee plant disease in the area. One key informant reported that this had in effect shortened the dairy value chains serving Moshi, as the higher productivity had meant that milk from Hai district was sufficient to satisfy the town's demand, whereas previously it had to be sourced from even further afield. This implies that the disease risks posed by milk and *mtindi* may have reduced compared to past years.

While the vast majority of the dairy products being consumed in Moshi Municipality were unprocessed and informally marketed, there were nonetheless signs of a gradual shift towards processed, formal milk sale. Firstly, the policy environment – though not reflective of the current context – is clear in its ambition to move towards a formalised dairy industry marketing processed dairy products. Secondly, our fieldwork identified the tendency for MCCs to progress to becoming DPUs in the longer term. This is perhaps surprising, given the many difficulties that DPUs described in maintaining their business as a profitable entity. Nonetheless, there seemed to be an accepted view that setting up a MCC was the first step in the journey towards becoming a DPU, with this progression being a recognised way of "upgrading" in the value chain. Indeed, the roles were already blurred in some instances: for example, one MCC we visited had recently installed a cheese vat donated by Land O' Lakes. In response to orders from their in-town customers, they sometimes used this as a heating tank to boil a proportion of their milk which they then poured into buckets and converted to *mtindi*, to be sold unpackaged and in bulk. Thus this MCC was already undertaking a limited degree of processing, despite not being officially registered as a DPU. Thirdly, there was a sense among key informants and informal traders that the work these traders were engaged with was somewhat illicit and unsustainable long-term given the policy environment, as explained in a conversation with the following market trader:

> *The market trader explained that the business for mtindi is a little bit illegal because it is easily contaminated, so if there is an outbreak of cholera then the sale of mtindi is one of the first thing that is prohibited, unless the health officer inspects the mtindi and gives you a permit to sell. That last happened in 2008. Sensitivity always occurs when there is an outbreak, that's when the authorities become sensitive about the issue of legalising the business. The trader said that right now the government is fair and allows them the opportunity to sell mtindi, but in many senses mtindi is not allowed, and that's why many big places and processing units won't buy it. So they're just selling mtindi for now because the government is not disturbing them at the moment.*
> **Field notes from a visit to Kiborilоni market, 7 May 2014**

Finally, although a long way from completion, there were nascent plans for over twenty MCCs and DPUs in Hai district to collaborate together to build a jointly-owned modern dairy processing factory in Boma Ng'ombe, an industrial peri-urban settlement on the main road between Arusha and Moshi towns. This collaboration would allow the DPUs and MCCs to achieve economies of scale that would not be achievable if working independently. At the time of research, a site for the factory had been identified but the co-operatives were yet to agree to go forwards with the plan. If successful, the factory could fundamentally change the structure and function of the dairy value chains supplying Moshi. Not only would the MCCs and DPUs deliver milk solely to Boma Ng'ombe, but it could be envisaged that rural intermediary traders might choose to do this too, rather than travelling the extra distance to Moshi Municipality. This would result in a far higher proportion of the milk sold in Moshi Municipality being processed than is currently the case. Moreover, economies of scale could facilitate a reduction in the price of processed dairy products than seen currently, potentially increasing their desirability for consumers. Increased accessibility to milk and milk products that have been adequately heat treated to ensure pasteurisation would only serve to improve the safety of dairy products consumed by residents of Moshi Municipality. Indeed, a risk assessment model from Uganda concluded that constructing a milk processing centre in peri-urban Kampala and ensuring that milk traders always sold to this centre could potentially reduce the risk of human brucellosis to Kampala consumers by 82% (Makita *et al.*, 2010).

5.8 Conclusions

Characterising the milk and *mtindi* value chains in terms of their function has highlighted key areas in which systems of governance, economics, knowledge flow and adaptation can contribute to both increasing and decreasing the introduction and propagation of infectious pathogens within those chains, ultimately affecting FBD risk to the consumer.

Our findings demonstrated that the formal systems of chain governance (i.e. legislation and regulation) were highly complex yet failed to recognise or respond to the context in which the dairy value chains were working. This had several consequences: DPUs were both over-regulated and ineffectively regulated, reducing their competitiveness and fostering a market that favoured the sale of unprocessed milk; MCCs were not regulated at all despite being formally registered with local government, allowing sales of bulked unprocessed milk to occur with no inspection; formally registered retailers such as shops were not systematically inspected to ensure they complied with hygiene guidance; and informal actors eluded inspection entirely except in the case of disease outbreaks, where inspection was at best piecemeal. Collectively, these consequences demonstrate that the legislative framework likely inhibits dairy product safety rather than enhancing it.

Throughout the chains and particularly where formal regulation was absent, internal governance played a key role. Formal and informal value chain actors alike utilised systems of social capital and trust; community engagement and women's empowerment; belief systems; and sanctions as means to regulate chain function. These systems could work both to increase food safety by the desire to maintain good internal relationships through providing hygienic and good quality products, but could also increase the risk of pathogen introduction/propagation if chain actors valued maintaining these relationships over and above insisting on good quality products.

A significant degree of control was exerted over the chain by several non-human actants, including the products themselves by virtue of their perishability; ecological features such as season and topography; infrastructure such as electricity and roads; and materials and equipment. However, it should be noted that these actants do not exist in isolation, and while value chain actors themselves may not have had any power to control them, many were related to the wider socio-economic and political environment, and were also interlinked. For example, investment in better roads would decrease the effect of season on the temporal length of value chains as it would not take so long to negotiate muddy roads; likewise, contamination with dust or mud spatter would reduce leading to improved hygiene and food safety.

Analysis of milk and *mtindi* prices suggested there was little willingness to pay extra for a product that had been processed (milk/*mtindi*) or that had been made from fresh rather than leftover milk (*mtindi*). This may reflect a lack of consumer awareness of product differences rather than a lack of interest in food safety. The profitability of participating in the chain varied between value chain actors; the milk/*mtindi* trade could be a supplementary income or an actor's main livelihood. There were also non-monetary benefits to participating in the chain. Nonetheless, profitability was always precarious which encouraged practices that could compromise food safety, e.g. adulteration or converting unsold milk to *mtindi*.

Formal training played a minimal role in knowledge generation and transfer within and along the value chains and was largely limited to upstream in the chains (smallholder farmers, DPUs and MCCs). Internal social networks were far more critical to disseminating knowledge, again demonstrating the key importance of social capital. As well as gleaning knowledge from others, value chain actors also relied on knowledge they gained through observation and experience. Knowledge generated through technology was limited. The reliance on internal systems of knowledge transfer rather than formal education or technology meant that many value chain actors had no specialised knowledge on dairy product hygiene and safety. This created a situation in which behaviours that could introduce infectious hazards could perpetuate within the chain. Barriers to specialised knowledge flow included: lack of motivation to learn (as value chain actors could operate efficiently without it); lack of time; limited access to expertise; and lack of financial or social capital.

The milk and *mtindi* value chains were frequently required to adapt to short-term changes in supply and demand caused by season or yearly events. The chains adapted by modulating what products were sold to whom and at what prices. These changes could potentially impact on food safety; for example, in the wet season when milk supply was more plentiful, more milk remained unsold at the end of a day. This led to more *mtindi* made from leftover milk being available on the market, a product which is likely to be more highly contaminated with pathogens than *mtindi* made from fresh milk. Longer term adaptations included a shift towards rural-to-urban supplies of milk/*mtindi* rather than local supplies from urban livestock keepers, implying higher risk to the consumer as value chain length increased both temporally and spatially, and the number of actors handling products between cow and consumer increased. However, emerging plans to build a large modern processing unit on a main road just outside of Moshi Municipality could lead to a fundamental change in how milk and *mtindi* is supplied to the town, potentially affecting every dimension of those value chains. Ultimately these changes could lead to a far higher proportion of milk and *mtindi* arriving in the town having been adequately processed to ensure pasteurisation. Furthermore, these products would have travelled a far shorter distance since being processed along much better quality roads. Should they go ahead, these plans have the potential to make a large impact on diminishing the infectious disease risks posed to Moshi residents by consuming milk and *mtindi*.

6 Assessing food-borne infectious disease risks along the milk and *mtindi* value chains supplying Moshi Municipality

6.1 Summary

Dairy products, while an important source of nutrition, potentially harbour many pathogens harmful to health. The milk and *mtindi* consumed by residents of Moshi Municipality are primarily supplied through value chains originating from smallholder farmers in rural surrounds or from urban livestock keepers locally. Microbiological studies have shown that during its journey from cow to consumer, milk sold in value chains similar to those supplying Moshi becomes increasingly contaminated with bacteria and potentially more risky to human health, although these studies do little to address either why this occurs or how consumers perceive and respond to these risks. Microbiological value chain studies are lacking for fermented milk products such as *mtindi*, but current evidence suggests that the souring process does not eliminate hazardous pathogens. Our research within Moshi Municipality suggested that Moshi residents were well aware of the infectious risks posed by milk, and took action to mitigate those risks by boiling milk before consumption. However, they showed less concern for the infectious risks potentially posed by *mtindi*, despite not being able to mitigate against them by boiling. Through value chain risk assessment, I identified the bulking, wholesale, and retail processes in the rural-to-urban value milk and *mtindi* chains to be risk hotspots for infections. Milk and *mtindi* produced by urban livestock keepers in town avoided these hotspots and were estimated as low risk to the consumer. Risk posed by milk produced in the rural-to-urban chain was deemed low-medium as consumers could eliminate pathogens by boiling. *Mtindi* made from fresh milk in the rural-to-urban chain was deemed higher risk than milk as consumers could not take mitigating steps to eliminate contaminating pathogens before consumption, and *mtindi* made from unsold milk in town was estimated to be high risk as the leftover milk used to make it was assumed to be highly contaminated with bacteria. Our findings suggest that although consumers perceive *mtindi* as a less risky product compared to milk, the reverse might in fact be true. More studies are needed into the microbiological hazards carried in fermented milk products such as *mtindi* in order to confirm or refute this hypothesis.

6.2 Introduction

Although dairy products are an important source of nutrition in many regions of the world, they also have the potential to harbour many pathogens, particularly bacteria, that can cause human illness (Table 1-1, Chapter 1). This is particularly so in contexts where pasteurisation is not the norm, and where hygiene standards along dairy value chains are poor. Investigation into the consumption of dairy products in Moshi Municipality and the value chains supplying them revealed that the principal dairy products consumed by Moshi residents were unpackaged milk and *mtindi* produced by smallholder farmers either in the surrounding rural areas or in the town itself. Previous studies from the East/Sub-Saharan African region have sampled milk from various points of similarly structured dairy value chains supplied by smallholder farmers and/or serving urban populations, and tested these according to standard milk quality indicators such as Total Bacterial Count (TBC) and Total Coliform Count (TCC). TBC measures the number of any kind of viable bacteria present in milk and includes both bacteria introduced directly from the cow (e.g. *Brucella abortus*) and introduced through contamination during or after milking. TCC measures the number of coliform bacteria in the milk, and higher counts suggest faecal or environmental contamination. The studies have consistently shown bacterial contamination of dairy products to increase along the chain, indicating potential increased risk to consumer health (Omore *et al.*, 2001; Grimaud, Sserunjogi and Grillet, 2007; Kilango *et al.*, 2012; Lubote, Shahada and Matemu, 2014; Doyle *et al.*, 2015; Joseph, 2015; Knight-Jones *et al.*, 2016). There is therefore substantial evidence to demonstrate that milk contamination with bacteria increases with increasing distance from cow towards consumer; however, few studies address where this contamination occurs or offer explanations as to what drives this phenomenon. Moreover, although longer dairy value chains can be considered as generally posing a higher infectious disease risk to the consumer, this does not mean that short value chains are themselves risk-free, nor guarantee that short value chains are always safer than long value chains; rather, this depends on a multitude of factors and activities occurring along the chains in question. In any case, the distinction between what comprises a “short” versus a “long” value chain is somewhat arbitrary.

Although fermented milk products such as *mtindi* are consumed all over Africa and elsewhere in the developing world, the evidence surrounding the quality and potential safety hazards of these products is far more limited than that for liquid milk. While there is recognition within the scientific literature that the souring process will inhibit or kill at least some bacteria, few studies have specifically examined the effectiveness of this in practice, including in settings where fermented milk consumption is common (Jans *et al.*, 2017). Even studies which refer to fermented milk as potentially risky have failed to evaluate these risks as in their own right, maintaining a focus on unpasteurised milk (Omore, Arimi and Kang'ethe, 2002; Knight-Jones *et al.*, 2016). A small number of studies have investigated the effect of the souring process on bacterial survival in fermented milk products under experimental conditions. Some have demonstrated the souring process inhibits *Brucella melitensis* and coliforms, (El-Daher, Na'was and Al-Qaderi, 1990; Tsegaye and Ashenafi, 2005), but others have shown that several bacteria remain viable despite low pH conditions, including *Salmonella* spp, *Staphylococcus* spp and *Listeria* spp (Ashenafi, 1993, 1994), *Mycobacteria* spp (Minja, Kurwijila and Kazwala, 1998), *Escherichia coli (E. coli)* O157 (Tsegaye and Ashenafi, 2005) and *Brucella abortus* (Zúñiga Estrada *et al.*, 2005).

A limited number of field studies have shown similar results to these experimental studies. For example, Yigrem and Welearegay (2015) assessed the microbiological qualities and safety of *Ergo,* a fermented milk product popular in Ethiopia. Although the counts of hazardous microbes in *Ergo* samples were lower than in raw milk, the overall microbial count was still above recommended standards and considered potentially hazardous to health. Yilma and Faye (2006) found similar results when investigating coliform counts in *Ergo* versus milk sampled from shops in the central highlands of Ethiopia. Hempen *et al.* (2004) compared the microbiological status of raw and fermented milk collected from local markets in The Gambia and Senegal and found that high levels of coliforms, principally *E.coli*, and of *Staphylococcus aureus* persisted in 21% and 15% of the fermented milk samples respectively, although counts were lower compared to raw milk. Finally, in Uganda Knight-Jones *et al.* (2016) found that counts of *Staphylococcus* spp, *Streptococcus* spp and *E.coli* in fermented milk were similar if not lower than fresh milk at point of purchase, but no different for *Bacillus* spp. Collectively, these studies suggest that while souring may reduce bacterial counts, it affects the viability of different bacterial species to different extents and is not sufficient to eliminate risk to human health. None of the studies have considered questions of bacterial contamination risks along the value chain, and none described how the fermented milk products in question had been produced, e.g. from boiled versus raw, or fresh versus leftover, milk.

It is thus clear that both the milk and *mtindi* supplied to Moshi Municipality could potentially contain infectious pathogens harmful to human health. However, it is unknown how consumers respond to these risks. Moreover, there is little information to suggest how and why infectious disease risk is introduced along the milk and *mtindi* value chains supplying consumers. This chapter seeks to address these data gaps. I begin by examining consumer knowledge, attitudes and behaviours related to the health risks associated with milk and *mtindi* consumption, using data generated through working with Moshi Municipality residents in the first stage of fieldwork. I then conduct a systematic risk assessment along the milk and *mtindi* value chains, using data about the structure and function of these value chains, and the risk practices undertaken by them, generated through working with actors participating in those chains.

6.3 Consumer risk perceptions and practices

6.3.1 Methods

We used a variety of research methods in our work with consumers, each of which explored patterns of dairy consumption and acquisition, together with knowledges, attitudes and beliefs with regard to the health benefits and risks of dairy products. The methods are described in full in Chapter 3. Briefly, we conducted a survey of 151 households across ten wards in Moshi Municipality, randomly selected with probability proportional to size of the ward population. We also conducted nine key informant interviews with relevant ward-level officials (e.g. ward executive officers and livestock field officers, and health officers) from all of the wards in which we were working and the chair of the Tanzania Dairy Board, as well as with dairy representatives at Moshi Municipality district office. We conducted group discussions in eight of the wards and proportional piling exercises with seven of these groups. Finally, we conducted twelve in-depth interviews with thirteen Moshi Municipality residents who had been invited to participate in the survey. Quantitative data were analysed in Stata (StataCorp, 2015), and qualitative data were thematically analysed with the aid of NVivo software (QSR International Pty Ltd, 2012) (see Chapter 3 for more details).

6.3.2 Results and discussion

Moshi residents considered dairy products to be healthy, with 93% of survey respondents (n=151, 95%CI: 83% - 98%) agreeing with the statement "Dairy products are good for health". However, research participants also recognised that there were health risks inherent in dairy product consumption. Ninety two survey respondents (62%, 95%CI: 53% - 70%) agreed with the statement that "Dairy products can cause illness"; moreover, several of the 18 respondents who disagreed went on to qualify this explaining that in order to avoid illness, one had to boil milk before consumption (unfortunately these qualifications were not recorded systematically on the survey, thus exact numbers are unknown). Survey respondents who agreed that dairy products could cause illness were then asked to name any specific illnesses they cause (Table 6-1). This was a non-prompted survey question and the categories presented in Table 6-1 were coded by myself according to respondents' answers.

Table 6-1 Non-prompted responses by survey participants (N=151) regarding diseases caused by dairy products

Disease reported	Percentage of respondents (n, 95% CIs)
Tuberculosis	25% (37, 19%-33%)
Gastrointestinal disease (e.g. diarrhoea, stomach cramps)	20% (29, 14%-26%)
Parasitic infections	11% (17, 7%-18%)
Diseases from cows (other than TB)	9% (13, 5%-16%)
Allergies	4% (5, 1%-15%)
High cholesterol	1% (2, 0.3%-6%)

The results from the survey supported the qualitative findings, where gastrointestinal illness was cited most frequently as a potential health risk associated with dairy product consumption, followed by TB or chest/lung problems; parasitic infection; diseases from the cow (other than TB); allergies; and finally cholesterol (Table 6-2).

Table 6-2 Number of consumer group discussions/in-depth interviews in which particular health risks were cited as a possible consequence of consuming dairy products

	Number of group discussions in which mentioned (n=8)	Number of in-depth interviews in which mentioned (n=12)
GASTROINTESTINAL		
Diarrhoea	6	5
Stomach problems	2	2
Constipation	1	0
PARASITIC		
Worms	4	3
Amoeba	1	1
TB/RESPIRATORY		
Chest or lung problems	2	0
TB	3	5
DISEASES FROM COWS (OTHER THAN TB)		
Brucella	0	3
General (e.g. fever)	1	1
Anthrax	0	1
OTHER		
Allergy	1	2
Cholesterol	0	1

Boiling milk before consumption was almost universal. Filtering milk (either before or after boiling) to remove dirt and cow hair was also common practice. Of 145 survey respondents who reported consuming boiled milk, 71% (95% CI: 60% -80%, n=103) explained in a non-prompted question that they did so in order to kill microbes and/or prevent illness. These reasons were also cited in all twelve in-depth interviews and seven of the eight group discussions.

Our qualitative research found that boiling milk was almost always the responsibility of the consumer rather than the vendor. Explanations given for this by key informants and by value chain actors alike were that vendors preferred not to boil large quantities of milk as this was costly in terms of both firewood and of time, and also resulted in a lower quantity for sale. The exception to this was when milk was being sold for immediate consumption on the premises, e.g. at a cafeteria or local shops. In this case, milk would invariably be boiled by the vendor and then stored in a thermos until sale to maintain its temperature:

Healthy adults on a hot day will go to a shop and get a cup of cold mtindi. They would never drink a cup of cold milk from a shop because they're not sure it's been boiled.
Key informant interview, Njoro Moshi ward, 30 October 2013

> *If buying milk from a shop, rather than directly from a farmer, it should be hot. If you buy cold milk from a shop, you know you should boil it.*
> **Key informant interview, Boma Mbuzi ward, 31 October 2013**

The above two quotations demonstrate how consumers only found milk to be acceptable to drink outside the home if they could be certain it had been boiled. Thus, while Moshi residents viewed milk as a very healthy and nutritious product, they nonetheless were informed about and recognised the potential disease risks it carried, and were highly motivated to mitigate those risks by boiling before consumption; indeed, the idea of drinking raw milk verged on the taboo. However, attitudes towards consuming *mtindi* were far more ambivalent. The results of the consumer survey showed that approximately 90% of consumers did not know whether *mtindi* had been made from boiled or raw milk, although of ten interviewees who were asked whether they preferred *mtindi* from raw or boiled milk, six said they preferred boiled, two preferred raw, and two had no opinion.

Given the widespread agreement that milk could cause illness and the almost universal consumer practice of boiling to prevent this, it seems counterintuitive that food safety concerns around milk did not extend to the consumption of *mtindi*. The literature on sociology of risk helps to contextualise some of the explanations that we encountered for this phenomenon. For example, Green (2009) argues that disease risk might simply not be a priority narrative for consumers when making decisions about food choices, and that they may have competing priorities, agenda and framings. She argues that other discourses such as nutrition might take precedence, and that risk might not feature as a prominent framing at all. In her work with consumers from four European countries during the Bovine Spongiform Encephalopathy (BSE) crisis, Green found that consumers were not overly concerned with disease risk when making their food choices; they were not in a state of anxiety and viewed food choice as rather routine and even mundane, not requiring much thought. In our research, four of thirteen interviewees reported alternative narratives taking priority over risk, in particular taste, texture, and product enjoyment, as exemplified by the quotes below:

> *…mtindi that is made by boiled milk doesn't clot well and ends up watery, but mtindi that is made by raw milk, if it's not disturbed, will clot well and is nicer.*
> **In-depth interview with consumer 06PAS23, Pasua ward, 6 December 2013**
>
> ***Do you think that if you knew mtindi also had germs that you might want to have mtindi that was made from boiled milk?***
> *I would prefer to buy mtindi made from boiled milk because I know milk has germs, but the problem is not everybody would make mtindi from boiled milk. And I really like mtindi, so there's no way I wouldn't drink it – I'll just drink it anyway.*
> **In-depth interview with consumer 00LON02, Longuo ward, 15 November 2013**

However, the idea that consumers were not overly concerned with disease risk when choosing dairy products is not supported by other results in this study in which concern was expressed about the risks posed by consuming raw milk. An alternative explanation could stem from the fact that while it was possible for the consumer to mitigate the potential disease risks of raw milk by boiling, it was not possible to mitigate the risks potentially posed by *mtindi* as it is consumed as purchased with no preparation step. In a paper examining the attitudes and behaviours of householders living in flood-risk areas, Harries (2008) enlists the idea of "ontological security" as an explanation as to why it can seem better not to protect oneself against a natural hazard. A concept coined by Giddens (1991), Harries describes ontological security thus: "*an ontologically secure person is someone who is free from existential doubts and who is able to believe that life will continue in much the same way as it always has, without threat to the familiar representations of time, space and identity*" (Harries 2008, page 482). Harries argues that the protection of ontological security by suppressing awareness of a continued risk that one cannot do anything about is rational and can protect one's mental health. The desire to *feel* secure will sometimes deter people from taking preventative actions, precisely because such measures might threaten the fundamental human need to feel secure (Harries, 2008). Extending this to *mtindi*, it could be hypothesised that, as there is little a consumer can do to limit the infectious hazards posed by *mtindi* (as opposed to milk, which they can boil), it is a rational act to suppress any conscious awareness of the continued risk that *mtindi* might pose. By not recognising *mtindi* as potentially risky, consumers are prioritising their ontological security over the security of their physical health.

This is an idea supported by Zinn (2009), in a critique of Green's work on BSE. Zinn argues that the responses of the consumers Green interviewed did not necessarily prove a lack of anxiety when considering food choices, but perhaps demonstrated that that individuals try to maintain the belief they can control these issues at least to a degree. He goes on to discuss the role of personal agency (or lack of it) in constructing a personal sense of risk, arguing that *"a negative event only then becomes a risk when it is linked to a decision. Only when we think that we can do (or should have done) something about an event (or its impact) is it no longer seen as the result of external forces but something which is in our responsibility."* (Zinn 2009, page 519). This argument helps to underpin the explanations given by three interviewees relating their lack of agency to help ensure *mtindi* food safety being linked to their not framing *mtindi* consumption as a risk problem. Following Zinn's logic, these respondents may not have perceived consuming *mtindi* as a risky activity as it was outside the realms of their capability and responsibility to ensure that the product was disease-free. The following quotation from a consumer gives a direct example of such a phenomenon occurring:

> ***You talk about boiling milk because it may have worms and other disease, do you also worry about the mtindi made without boiling milk?***
> *We worry, but what can we do? While mtindi which is made by raw milk is good when you use it with ugali, the mtindi which is boiled is not good because it will have some water.*
> ***So for mtindi, the taste is more important than the health?***
> *Because we don't use it every day, and when it happens it's bad luck*
> **In-depth interview with consumer 03KAL18, Kaloleni ward, 29 November 2013**

This respondent refers to their lack of agency ("what can we do?") to ensure that *mtindi* is safe given that the taste or texture (a competing narrative) of *mtindi* made from raw milk is superior. Risk is then externalised: any disease that might arise is attributed to "bad luck" rather than the responsibility of the respondent for consuming *mtindi* made from unboiled milk. A second respondent alluded to their lack of agency as the reason for not previously considering *mtindi* consumption as a potential disease risk:

> ***I'm interested why people here seem to find boiling fresh milk very, very important, but not so much for mtindi. Why is it OK to eat mtindi that's not made from boiled milk, but it's not OK to drink fresh milk that's not boiled?***
> *I can't really tell the reason why this always happens, but for me I don't ever drink raw milk but for mtindi I can drink it without considering whether it's from raw milk or from boiled milk, because I can't know if it's boiled or not.*
> ***In-depth interview with consumer 01MIE08, Miembeni ward, 22 November 2013***

Green (2009) also notes that different forms of knowledge compete to inform food choice, highlighting that personal anecdote and experience can be a powerful resource to both resist and support scientific or biological explanations of disease risk. Two interviewees cited personal experience as a reason to know that *mtindi* cannot pose a food safety risk, including the resident quoted below:

> ***So do you think that mtindi that's made from raw milk could make you sick, in the same way that raw fresh milk could make you sick?***
> *Not really. Mtindi can cause illness if it hasn't been made in clean conditions with no interference, but if it's been made in clean conditions without boiling the fresh milk, it can't cause illness. I've been consuming mtindi for a long time and never had problems.*
> **In depth interview with consumer 06PAS023, 6 December 2013**

However, while it is plausible that consumers might link consumption of *mtindi* to gastrointestinal illness, which tends to have a short incubation period, it would be much more difficult for consumers to link other illnesses caused by pathogens potentially carried in *mtindi* to consumption of the product. For example, brucellosis has an incubation period of weeks to months and can have very non-specific symptoms that sufferers might not link so easily to the act of food consumption compared to gastrointestinal symptoms such as vomiting and diarrhoea (Table 1-1).

Finally, two consumers explained that *mtindi* could not be a source of the disease risks posed by milk because it was fundamentally different to milk. One linked this directly to the souring process, while the other explained that as *mtindi* was in an intrinsically different state to raw milk, it could not carry the same disease risks:

> ***If you could explain in more detail… Could you expand on why most people are wary of drinking fresh milk if it's not boiled, but they like to drink mtindi made with raw milk?***
> *If you drink mtindi, which is sour, it's not easy to be harmed, but if you drink raw fresh milk then you can get problems.*
> **In-depth interview with consumer 02MAJ21, Majengo ward, 22 November 2013**

> ***For the diseases that you can get from drinking milk which is not boiled, can you get them from drinking mtindi which is made by milk which is not boiled?***
> *No.*
> ***Why not?***
> *Because mtindi is like a food. You can add it to your porridge or ugali* [a dough made with maize flour]*, it's not in the same state that fresh milk is in – there are some changes that occur for it to be mtindi. So it's not likely to be dangerous like fresh milk.*
> **In-depth interview with consumer 03KAL20, Kaloleni ward, 29 November 2013**

Thus, although there were several possible explanations as to why consumers perceived milk as risky and mtindi less so, no one explanation stood out and the reasons behind this apparent disconnect merit further research. It should be noted that we did not explore if consumers had any concerns over whether *mtindi* was made directly from fresh milk or from leftover, unsold milk, as the value chain work that revealed this practice was carried out after the consumer work was complete. However, this consideration did not arise spontaneously in any of the group discussions or in-depth interviews with consumers, nor in discussions with any *mtindi* retailers. In addition, the lack of difference in pricing of *mtindi* made from fresh versus leftover milk suggests that consumers did not place value in distinguishing between the two types (the same can be said for *mtindi* made from boiled versus raw milk).

Having explored consumer knowledge of and responses to the disease risks potentially posed by milk and *mtindi,* the next section explores where, how and why infectious disease risks might be introduced along the milk and *mtindi* value chains by means of a systematic value chain risk assessment.

6.4 Value chain risk assessment

6.4.1 Methods

In Chapter 2, I described a risk pathway analysis approach for value chain risk assessment, which involved ascertaining for each value chain strand all of the steps along the path from "stable to table" through which infectious pathogens might be introduced and/or propagate, and using the information generated by fieldwork and literature review to estimate risk as a product of the probability of these events occurring, and the impact should they occur.

To collect the relevant data, I designed a survey tool for each value chain actor group which organised value chain and risk information according to categories described by the Codex Alimentarius (CA) Food Hygiene Basic Texts (2009); CA Code of Hygienic Practice for Milk and Milk Products (2009a); and Standard for Milk and Milk Products (WHO&FAO 2011). These categories systematically set out the sequential premises, practices and procedures that are involved in the journey of a dairy product from stable to table, and the factors pertaining to these premises, practices and procedures that must be examined in order to make informed judgements on disease risk. Examples of these survey tools can be found in Appendix 3; however, for reference, examples of categories included infrastructure (with factors to consider including premises location, layout and structural integrity; water and electricity supply; surfaces, structures and fittings within the premises; and access by pests), or handling and storage practices (considering factors such as locations stored; containers and equipment used; time and temperature stored; staff hygiene; and cleansing and disinfection procedures).

I completed surveys for the 56 value chain actors recruited by collating data from the interviewing, participant observation, and surveying techniques described in Chapter 4. Together with supplementary field notes and insights from the consumer survey, group discussions and key informant interviews, these surveys comprised a dataset of qualitative and semi-quantitative information to be interrogated for the risk assessment.

All risk assessments begin by identifying the hazard of interest and formulating the risk question concerning that hazard. For the purposes of my research, the “hazard” was very broad – essentially, any bacterial pathogen that is harmful to human health when ingested. As a consequence, the risk question was also broad: “what is the risk of bacterial pathogens harmful to human health being disseminated further as a result of activities at this stage of the value chain?” The advantage of a broad risk question was that it was sensitive and could capture a wide range of risky activities, both those that would introduce bacteria to the value chain and those that would foster bacterial propagation. The disadvantage was that it was not specific to any type of bacteria, so it was not possible to consider how various activities along the chain could differentially affect different types of bacteria (e.g. bacteria such as *Brucella* introduced at milking versus bacteria such as *E. coli* introduced later on in the chain through contamination). This point will be returned to later when discussing the results.

I then developed a tabular framework through which I could systematically organise data and information pertaining to each pathway step, sorted by value chain actor. Table 6-3 presents two worked examples of this. Both examples examine the bulking step common to the milk and *mtindi* rural-to-urban value chains. The first example considers intermediary traders and the second considers DPUs. The first column of the risk assessment table showed the various elements of the bulking step that should be considered in the risk assessment, based on the CA Good Hygiene Practices (Codex Alimentarius 2009; WHO & FAO 2011). The second column recorded factors that increased the risk of introduction or propagation of pathogens, and the third column factors that decreased risk of the same. The forth column allowed contextual information to be added, and the fifth column referenced findings of relevant literature. Through assimilating this tabulated information, I assigned estimated categorical qualitative probabilities (very low – low – medium – high – very high) for each risk pathway step. Each probability represented the likelihood that the milk or *mtindi* emerging from the pathway step under consideration would contain sufficient bacterial pathogens to potentially harm human health owing to these pathogens having been introduced or propagated through activities during that pathway step. For example, when considering intermediary traders, a picture emerged of poor environmental hygiene, poor quality testing, unhygienic handling practices and inadequate equipment (Table 6-3). Therefore, I estimated the probability of introduction or propagation of pathogens at this point as very high. When considering DPUs, the picture generated of environmental hygiene, quality testing, handling and equipment was more positive; however, some practices did increase risk (e.g. repeated dipping and scooping of milk during the collection process; obliging sick staff members to attend work) and moreover milk was collected in large quantities from a large number of farmers. Therefore, I assigned the probability as medium.

Similarly, I assigned estimated impacts (negligible – minor – moderate – major – severe) at each pathway step, representing the potential impact of milk or *mtindi* that contained sufficient pathogenic bacteria to harm human health emerging from this step. In estimating this parameter, I took into account the volume of milk/*mtindi* disseminated from the pathway step given the value chain actor under consideration, assumptions about bacterial load given hygiene and storage conditions at that and previous stages in the value chain, and information regarding the number of actors to whom this milk/*mtindi* might be distributed. The exception to this was when considering consumers as value chain actors, in which case the focus of the impact was on the individual consumer[14]. For example, I was aware from the value chain analysis that the quantities of milk and *mtindi* distributed by intermediary traders, and the number of clients they distributed to, were lower compared to other value chain actors, particularly for traders who did not have their own transport. However, the bacterial load of the products was assumed to be high. Therefore, I estimated the impact as moderate to major. For the DPU, I rated the impact of contamination as minor as the milk collected at this step would not be

[14] Estimating the impact to a consumer at an individual level meant that consumer risk was estimated as that incurred by an individual consumer, rather than by all Moshi dairy consumers collectively. This allowed for the risks posed to the consumer by less dominant strands of the value chains (e.g. urban-to-urban milk chain) to be directly compared to more dominant strands (e.g. rural-to-urban milk chain). Had consumers been examined as a collective, less dominant strands would by default have been considered low risk as they served fewer residents than the dominant chains.

disseminated further in its current state (i.e. it would remain at the value chain node to be heat treated) (Table 6-3).

After estimating probabilities and impacts, I used the risk matrix presented in Chapter 2 (Figure 2-2) to account for both probability and impact parameters and arrive at a final estimation of risk as Green (low), Yellow (medium) or Red (high). Having gone through each risk pathway for each value chain actor in turn (the full output of which can be found in Appendix 4), I depicted each risk pathway as a process map with the relevant value chain actors listed underneath each step, colour-coded in the relevant colour according to the risk they posed at that step. This presentation allowed for easy visual identification of risk hotspots, comparison of the risks posed by different value chain actors at each step, and tracking each value chain actor type along the risk pathway to locate which steps are of particular concern for that actor. This is the first time that the findings of a value chain risk assessment have been presented in this way.

Table 6-3 Worked example of a completed risk assessment table examining the bulking step of the risk pathway by intermediary traders and DPUs

Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further context and comments	Relevant literature
INTERMEDIARY TRADERS				
Collection procedure		Bulk from a smaller number of farmers compared to MCCs/DPUs - most (80%) collected from between 10-20 farmers.		Prevalence of Brucella PCR+ milk samples increased from 10% (farmers) to 31% of intermediary traders in Morogoro dairy value chain (Joseph, 2015)(Tanzania, 2015)
Environmental hygiene	For traders who collect at home: collection area is at homestead rather than in a purpose built area, thus environmental hygiene is often lacking, e.g. collection taking place in muddy/dusty back yard in an area where surfaces cannot be properly kept clean. For traders who collect milk from farmers: environmental hygiene is also poor; vehicles are open to the elements (e.g. pick ups and motorbikes) leaving milk collection vessels and equipment open for exposure to mud splatter and dust.			
Quality tests on receipt	Organoleptic tests were rare; 2/12 reported smelling milk; 1/12 tasted it; and 2/12 visually inspected it	9/12 reported at least occasional use of a lactometer to detect adulteration with water.	Report of lactometer use does not necessarily mean that the lactometer is consistently used. Two traders who reported using lactometers at interview did not use the tool when collection was observed. Six traders reported use, but collection was not observed so this could be verified.	In a study of milk quality along the dairy value chain in Nakuru and Nyandarua Kenya, Ndungu (2016) found that the lactometer could not always detect prior adulteration of raw milk with water.(Ndungu *et al.*, 2016)

Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further context and comments	Relevant literature
			Only one trader reported lactometer use which was then confirmed on observation	
	One trader reported that he was interested in the ethanol test, but that affordable supplies were inaccessible.	1/12 reported performing the clot-on-boiling test		
		8/9 would reject milk that they considered poor quality (1/9 would use it to make *mtindi*); 2 mentioned they would ban repeat offenders.		
Handling	Milk is mixed together, facilitating contamination of large quantities by even a single farmer's supply.			
	Participant observation revealed milk transfer between multiple containers, as well as scooping rather than pouring.			
	Participant observation revealed some unhygienic behaviours e.g touching manure whilst doing other activities during the collection process, without then washing hands.			
Equipment	Milk brought by farmers predominantly in plastic buckets or jerry cans; traders collecting milk (e.g. by motorbike) did so predominantly in 50 l jerry cans	One trader collected milk in small jerry cans from each individual farmer and did not mix them until the next morning, to avoid one farmer's milk potentially contaminating the entire supply.		

Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further context and comments	Relevant literature
	Where traders collected milk at their home, collection vessels were typically kept uncovered throughout the period of collection which could be up to an hour			
Estimated probability: Very high **Estimated impact:** Moderate to major **Estimated risk:** Yellow-red (Medium-high)				
DAIRY PROCESSING UNITS				
Collection procedure	Bulk from a large number of farmers (70-200)	Both DPUs collected milk in a designated area on a covered porch with a smooth cement floor		
Environmental hygiene		Environmental hygiene was good in both DPUs (e.g good drainage, unpolluted surroundings, etc)		
		Fast speed of reception at both DPUs, although one DPU reported that farmers could queue up to 30 minutes waiting for the DPU to open		
Quality tests		Both did lactometer test on all deliveries. One DPU did the ethanol test if they had suspicions that milk was spoiled/adulterated; the other did the ethanol test as a supplementary test of random farmers on random days of the week. One DPU also smelled milk		In a study of milk quality along the dairy value chain in Nakuru and Nyandarua Kenya, Ndungu (2016) found that the lactometer could not always detect prior adulteration of raw milk with water

Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further context and comments	Relevant literature
		delivered by motorbike intermediaries.		
		Both DPUs sanctioned bad quality milk with milk rejection, warnings and possible bans		
Handling	Practices increasing the risk of contamination observed at both DPUs observed e.g. dipping cups into milk, scooping to transfer milk			
		Most staff wore PPE at both DPUs, eg white coats and boots		
	One staff member reported that she was obliged to come to work even when ill as she was the only staff member who knew how to make a specific product	Staff at both DPUs reported washing hands before commencing each processing activity; note that handwashing facilities were sparse and that handwashing was not observed, so this may not be the case. However, it does denote at least an awareness of the need for good hygiene.		
Equipment	Milk brought by farmers predominantly in plastic buckets or jerry cans; traders collecting milk (e.g. by motorbike) did so predominantly in 50 l jerry cans	Both DPUs used hot water and soap to clean equipment		

Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further context and comments	Relevant literature
	DPU that collected into a tank left this tank open throughout the hour long collection period	One DPU collected straight into the cans that would then be heat treated, reducing transferral of milk		

Estimated probability: Medium **Estimated impact:** Minor **Estimated risk:** Green (Low)

6.4.2 Results and discussion

Using the information gathered during fieldwork, I described six different "risk pathways" – the sequential steps from milking to consumption at which pathogenic bacteria could be introduced or propagate and thus cause a risk to human health if ingested. There were two pathways for milk (rural-to-urban and urban-to-urban, corresponding to the two value chain strands described in Chapter 4) and four pathways for *mtindi* – (rural-to-urban Pathways 1 and 2, whereby *mtindi* was made directly for sale from fresh milk in Pathway 1, and made from leftover unsold milk in Pathway 2; and urban-to-urban Pathways 1 and 2, whereby *mtindi* was again made directly from fresh milk or from leftovers respectively).

The full risk assessment can be found in Appendix 4. The figures below present the six risk pathways elucidated for the rural-to-urban and urban-to-urban milk and *mtindi* value chains. The value chain actors active in each pathway step are listed underneath the relevant step, colour-coded according to the risk their activities pose at each step. Note that in some cases the risk was difficult to estimate as probability and/or impact were contingent on circumstance. Therefore, in some cases, the risk fell between Green and Yellow or between Yellow and Red. Thus, colour coding is according to the legend shown in Table 6-4:

Table 6-4 Legend for the value chain risk assessment pathways

Value chain actor (example)	Risk colour code	Risk level
• Farmer	Green	Low
• MCC	Green – Yellow	Low-medium
• Institutions	Yellow	Medium
• Int. trader	Yellow –Red	Medium-high
• Market	Red	High

Figure 6-1 Rural to urban milk value chain risk assessment

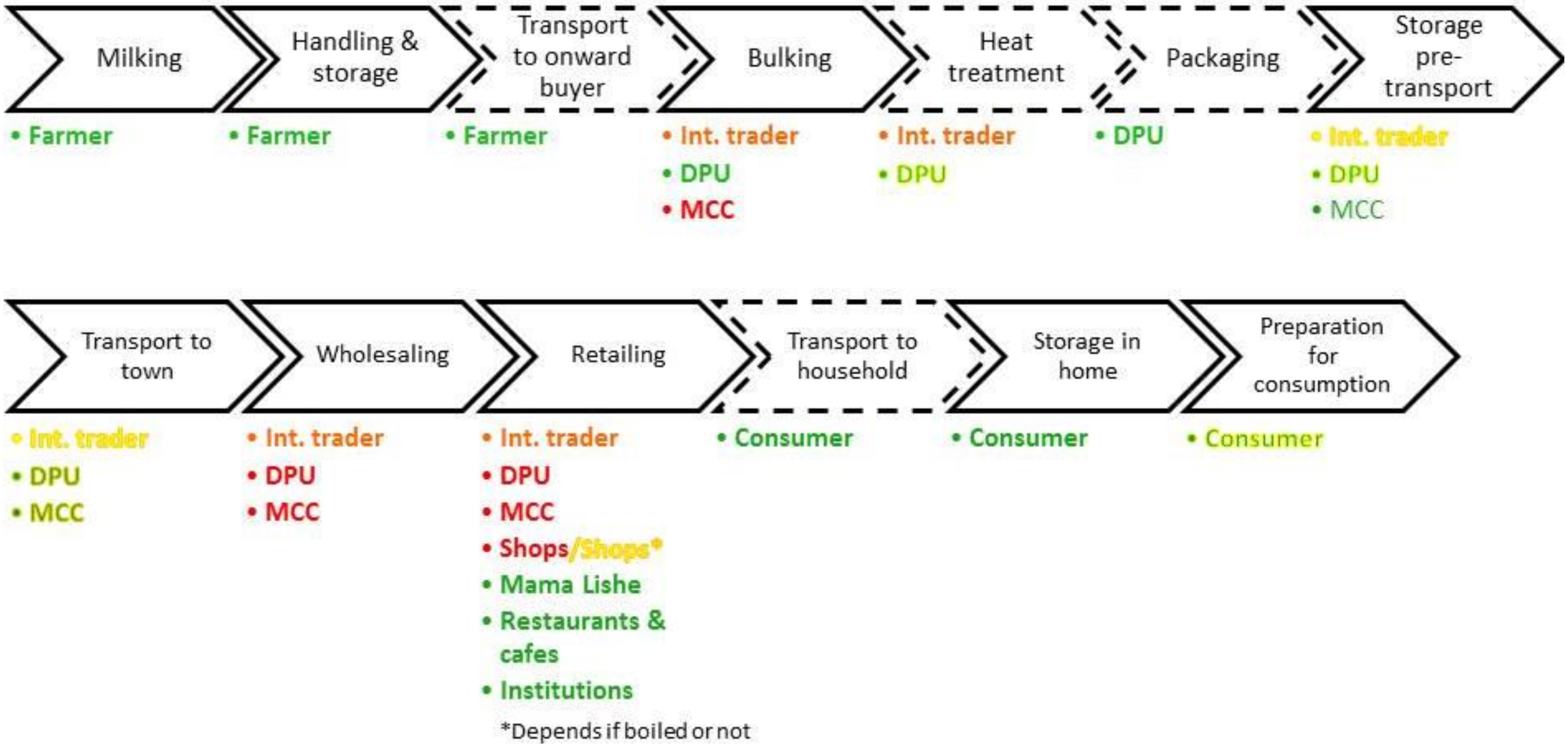


Figure 6-2 Urban to urban milk value chain risk assessment

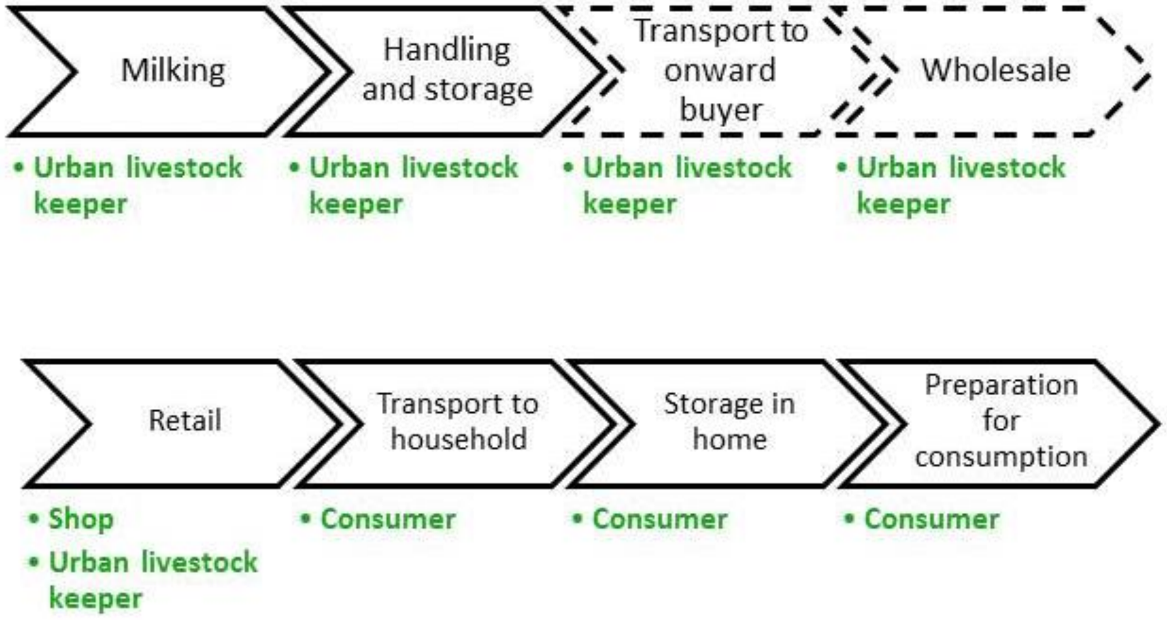


Figure 6-3 Rural to urban *mtindi* value chain risk assessment – Pathway 1
(made from fresh milk and originally intended to be sold as mtindi)

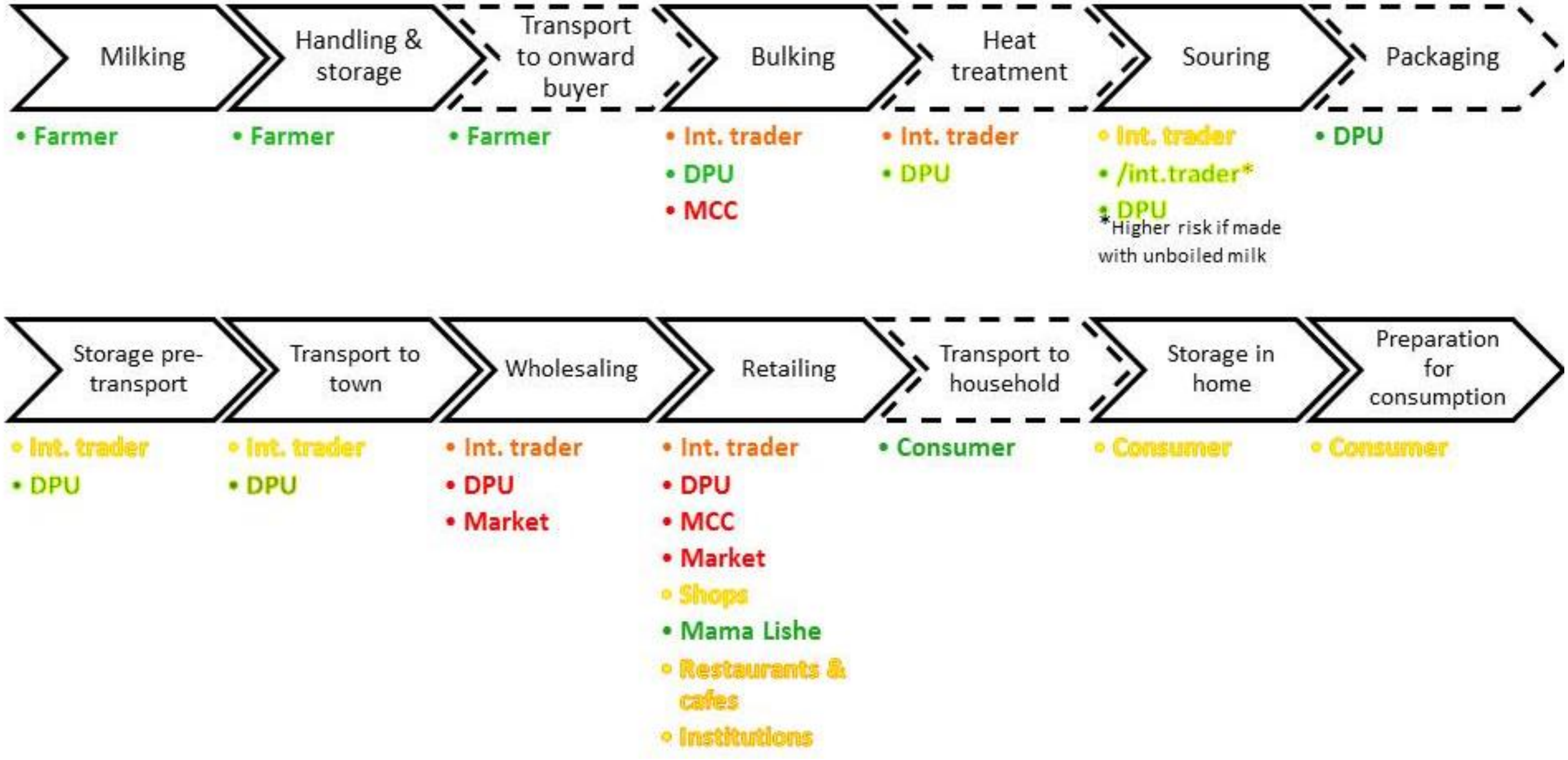


Figure 6-4 Rural to urban *mtindi* value chain risk assessment - Pathway 2
(made using leftover unsold milk brought back from town and soured for sale as mtindi)

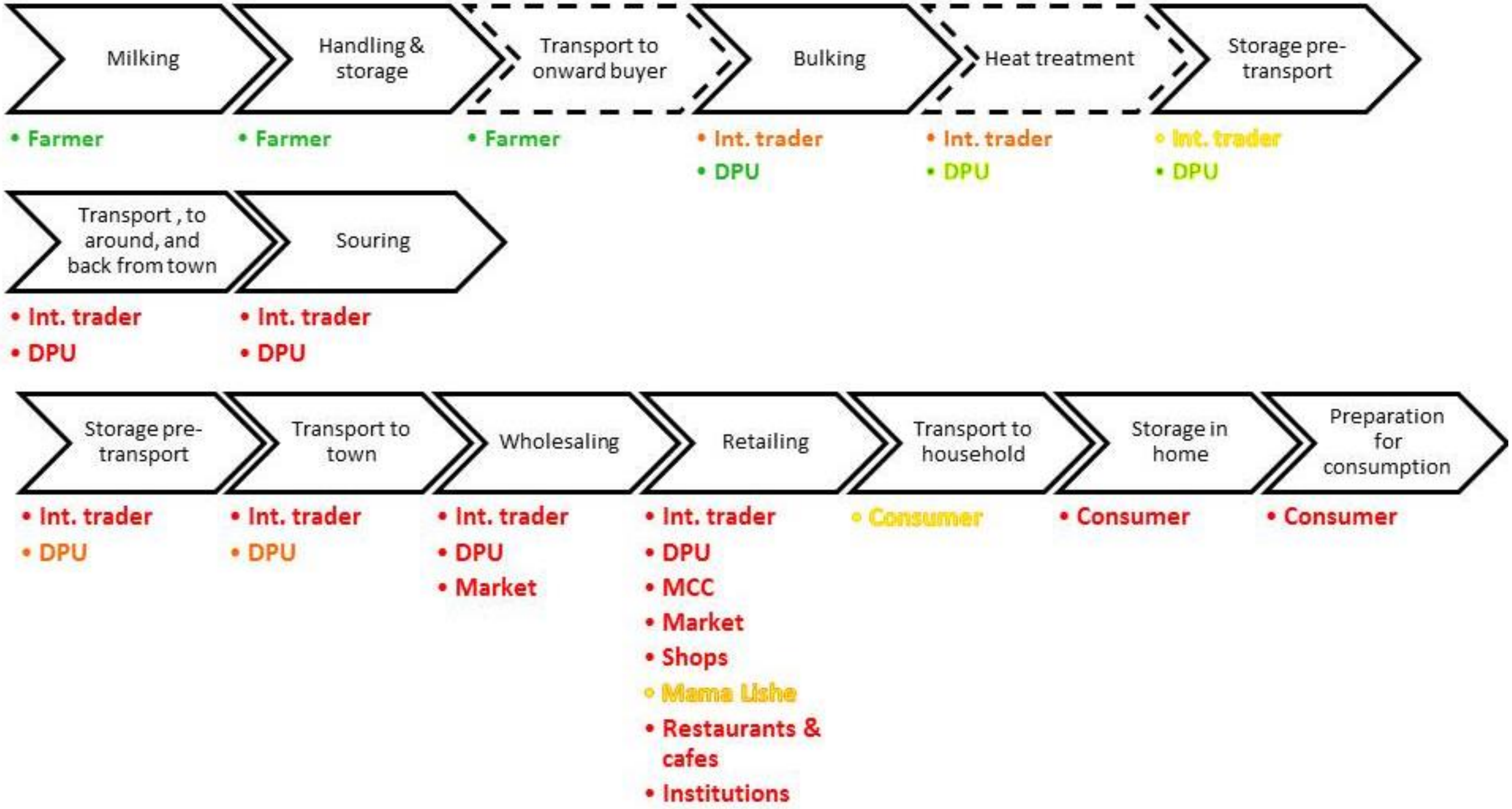


Figure 6-5 Urban to urban *mtindi* value chain risk assessment - Pathway 1 *(made from fresh milk and originally intended for sale as mtindi)*

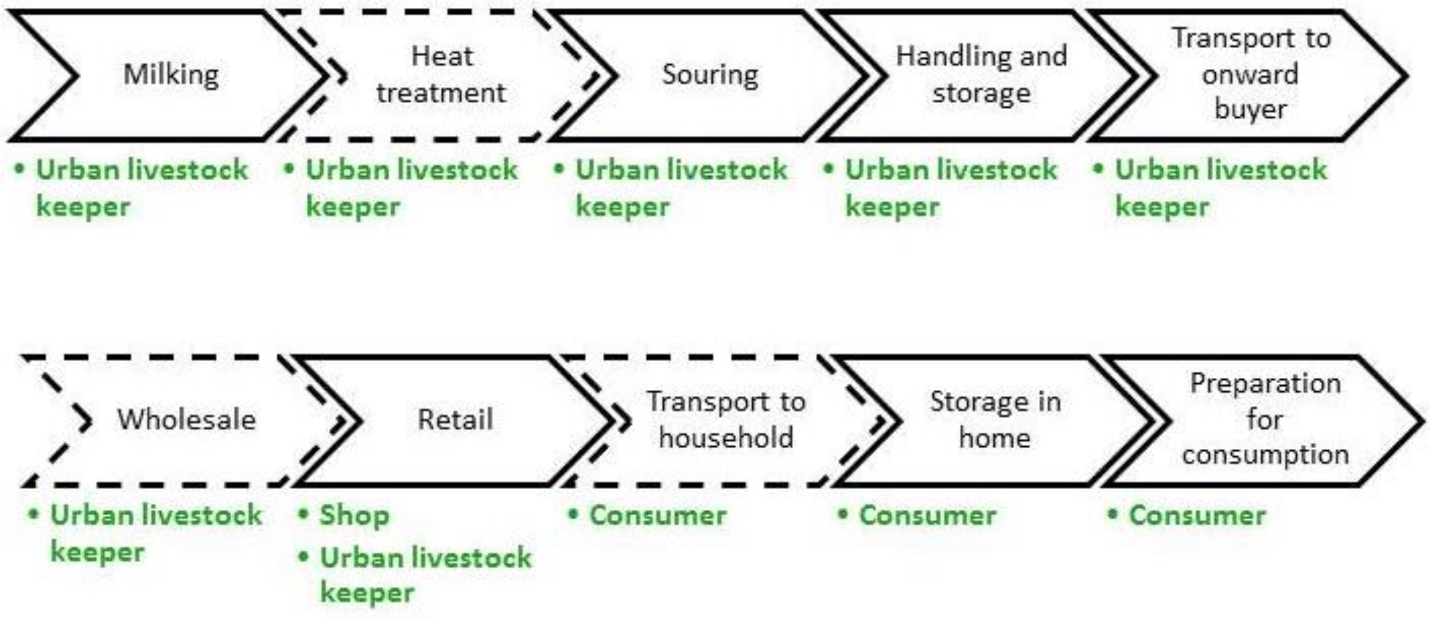
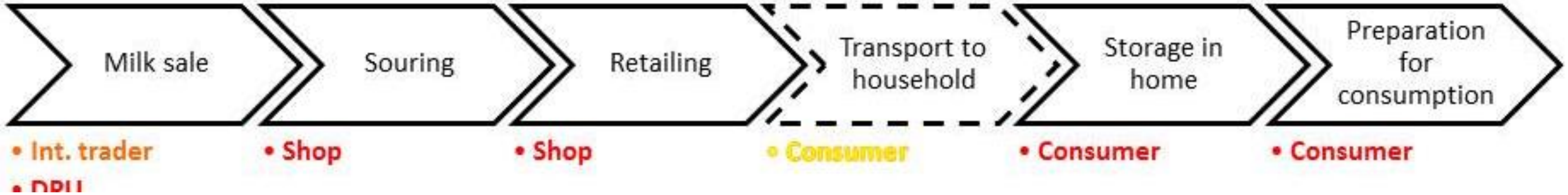


Figure 6-6 Urban to urban *mtindi* value chain risk assessment - Pathway 2 *(made from leftover unsold milk soured for sale as mtindi)*



The results of the risk assessment suggest that the urban-to-urban milk value chain and the urban-to-urban *mtindi* value chain, where *mtindi* was made from fresh milk rather than leftovers (Pathway 1), were the least risky of the value chain strands under consideration. This is because these chains were short, involved very few actors and involved small quantities of product compared to the rural-to-urban chains where products were bulked. This meant that there were fewer points of transaction and trade, thus milk and *mtindi* were handled less so bacterial contamination was less likely to occur, and the time period between milking and consumption of the product was much shorter, leaving less opportunity for bacterial propagation prior to consumption.

The rural-to-urban chains for milk and *mtindi* made from fresh milk each had similar risk hotspots, which is unsurprising given that largely the same sets of value chain actors were the involved in these chains, using the same equipment, modes of transport etc. The two main hotspots identified for both milk and *mtindi* (identifiable by the increased yellow/red colouring of the actors involved) were bulking, wholesale and retail. At the bulking stage, the milk from a large number of farmers was mixed, and from this point would be disseminated to a large number of downstream value chain actors. In addition, hygiene during collection, handling and storage was often inadequate, offering additional opportunities for bacterial contamination and proliferation. MCCs posed the highest risk at bulking as they sold a large quantity of milk to a large number of actors without further processing. DPUs posed a low risk at this stage despite bulking milk from a similar number of actors under similar circumstances, because the milk that they bulked would not be disseminated further in this state (rather, it would go on to be heat treated). Intermediary traders were rated as medium risk as, although their hygiene standards tended to be lower than MCCs/DPUs and they did not always heat treat milk, they each tended to sell lower quantities to fewer consumers. For wholesale and retail, the combination of a lack of cold chain, use of non-food grade plastic containers, unhygienic conditions and handling and protracted periods of sale together combined to provide ample opportunities for both bacterial contamination of and propagation in both milk and *mtindi*. Here, DPUs and MCCs were identified as the most risky value chain actors owing to the large quantities of product they sold, to many actors all over Moshi Municipality.

The risk assessment identified the riskiest value chain strands to consumers as the rural-to-urban *mtindi* chain (Pathway 2), whereby *mtindi* was made from leftover milk that had not been sold in town, and the urban-to-urban *mtindi* chain (Pathway 2), whereby *mtindi* was made in town from unsold milk. This finding was largely based on the assumption that the leftover milk used to make the *mtindi* would be highly contaminated with bacteria and thus the *mtindi* produced from it would be hazardous to health. Ideally, empirical evidence would be available to validate this assumption. However, I have found no study that investigates the microbiology of fermented milk products made from leftover milk, even though using this strategy to minimise dairy losses is unlikely to be restricted to Tanzania (indeed, the practice has been noted in Zambia (Knight-Jones *et al.*, 2016)). Nonetheless, Tsegaye and Ashenafi (2005) investigated survival of *E. coil* O157:H7 in *Ergo*, an Ethiopian fermented milk product, and found that test strains of *E.coli* O157:H7 inoculated into *Ergo* were eliminated after 6 hours of storage at ambient temperature, while test strains that were inoculated into the milk that was fermenting into *Ergo* survived. The authors hypothesised that the strains that were present during the fermenting process developed acid tolerance and could survive souring, while strains introduced directly to the soured product had no such tolerance and were killed by the low pH. This evidence would suggest that *mtindi* made directly from fresh milk would be less hazardous for *E. coli* O157:H7 than would *mtindi* made from milk that had already been contaminated with *E.coli* O157:H7 and had begun to sour, particularly given that numerous studies have shown that milk coliform counts increase along value chains, suggesting that leftover milk can be expected to be highly contaminated compared to fresh milk (Omore *et al.*, 2001; Grimaud, Sserunjogi and Grillet, 2007; Kilango *et al.*, 2012; Lubote, Shahada and Matemu, 2014; Doyle *et al.*, 2015; Joseph, 2015; Knight-Jones *et al.*, 2016).

Ultimately, the risk assessment estimated that milk consumption posed a low risk to health because urban consumers tended to boil milk prior to consumption, a mitigation measure that would remove almost all of the bacterial hazards present in the milk no matter how contaminated it had been before boiling. Milk from rural origins was estimated as slightly more risky because this milk would have had increased opportunities for bacterial contamination and propagation along the longer value chain, and consumers would potentially be exposed to a higher pathogen loads when consuming it if it was not adequately heat treated (fieldwork had suggested that not all consumers would boil milk or heat it to a sufficient temperature to ensure pasteurisation, and also shown that certain vulnerable population groups such as children, the sick and elderly who were at particular risk of succumbing to FBD also drank higher quantities of milk). *Mtindi* was estimated to pose a medium to high risk to consumers as there was no consumer behaviour comparable to boiling that could mitigate the bacterial risks potentially posed by the product. The exception to this was *mtindi* made in town from fresh milk, in short value chains with few actors: this was estimated as posing a low risk to the consumer.

There were several limitations to the risk assessment method as applied. I used a broad definition of hazard in the risk assessment, encompassing any bacterial pathogen that is harmful to human health when ingested without consideration of pathogen-specific risks. The advantage of this was that it enabled a risk assessment to be undertaken, capturing a wide range of potentially risky activities that could either introduce bacteria to the value chain or foster their propagation. The sensitivity of this risk assessment now needs to be assessed through further microbiological, epidemiological and other scientific research. Undoubtedly however, the broad and non-specific nature of the risk question imposed several limitations in the capability to differentiate the disease risks posed by different bacteria, value chain actors, and activities.

There are three main routes by which pathogenic bacteria come to be present in milk. The first is due to the bacteria being present in the milk in the udder itself, as a result either of a systemic infection of the cow (whereby the bacteria pass directly from the cow’s bloodstream to the milk) or of mastitis (infection of the udder). Thus, through this route, bacteria are present in the milk at the point of milking. The second is due to accidental contamination of the milk with bacteria. This might happen immediately at the point of milking (e.g. due to poor hygiene practices resulting in bacteria from cow faeces or skin entering the milk) or much later in the value chain (e.g. due to poor handling practices, inadequate cleansing and disinfection of equipment, or environmental contamination with infective organic matter, such as through mud splatter). The third is due to deliberate adulteration of milk with foreign substances in order to increase quantity for sale, mask poor quality, or extend shelf life, an increasingly common problem in developing countries as demand for milk increases in contexts where formal regulation of food and drink is lacking (Handford, Campbell and Elliott, 2016; Nascimento *et al.*, 2017).

Table 1-1 demonstrates that very few of the bacteria commonly found in milk are introduced exclusively through one route and not another. While *Bacillus cereus* will only ever be present due to contamination, *Listeria monocytogenes* could either have originated from an infected cow or from contaminated soil or water entering the milk further downstream the chain. For many pathogens, a particular route may be dominant, however. For example, *Brucella* spp in milk are almost always introduced via the first route due to systemic infection of the cow (American Public Health Association, 2008), whereas *Escherichia coli* spp may be introduced either by contamination with faeces at milking or later on in the chain due to poor hygiene. The result is that different points and practices in the value chain may be subject to different risks posed by different bacterial hazards. For example, the risk of *Brucella* spp being present in a dairy value chain increases with the practice of bulking, as many sources of milk are mixed together (Omore *et al.*, 2001; Arimi *et al.*, 2005; Swai and Schoonman, 2011; Joseph, 2015). However, the risk of coliforms being present in the chain increases as value chains become longer and more opportunities for contamination arise (Omore *et al.*, 2001; Grimaud, Sserunjogi and Grillet, 2007; Kilango *et al.*, 2012; Lubote, Shahada and Matemu, 2014; Joseph, 2015; Knight-Jones *et al.*, 2016; Ndungu *et al.*, 2016). Moreover, the risks posed by different pathogens might differ dependent on the value chain actor under consideration. This phenomenon was demonstrated by a study examining raw milk marketed in Tanga, Tanzania (Swai and Schoonman, 2011), which found that samples of milk sold by MCCs were more likely to contain *Brucella abortus* antibodies (67% samples) than milk sold by intermediary traders (33% samples), likely because MCCs collected milk from a larger number of animals and herds. On the other hand, milk samples sold by intermediary traders were significantly more highly contaminated with coliforms compared to MCCs (mean coliform plate count 4.2×10^6 compared to 3.0×10^6), likely because of poorer hygiene practices of intermediary traders together with the lack of chilling on collection. While the presence of *Brucella* antibodies does not necessarily equate to infectious

Brucella organisms being present in the milk, the findings nonetheless suggest that milk marketed by the two different actors may contain different hazardous pathogens and thus pose different types of risk to the consumer. However, the broad, non-specific nature of the risk question used in the VCRA in this research did not allow for this kind of nuance to be captured.

A further problem of the non-specific risk question is that it fails to take into account that particular activities in the risk pathway may affect what pathogens are present in the chain downstream of that step and thus shape what type of disease risks are posed. For example, heat treatment by a DPU or intermediary trader is likely to eliminate *Brucella* as a risk organism in the chain, but it will not serve to prevent heavy contamination with other bacteria further on. This could lead to a misleading impression that heat treatment upstream in the chain is an ineffective control measure for human health as the risk assessment concludes that heat-treated products still pose a risk downstream, even though the risk of brucellosis, and any other human pathogen coming direct from the milking cow (e.g. *Mycobacterium bovis*) will have been considerably reduced. Similarly, the risk assessment does not distinguish between *mtindi* made from raw milk versus *mtindi* made from boiled milk, although it is probable that initial heat treatment of milk prior to souring is likely to have an effect on the pathogens present in the eventual product. Experimental studies have shown pathogens such as *Mycobacteria* and *Brucella* to persist in fermented milk (Minja, Kurwijila and Kazwala, 1998; Zúñiga Estrada *et al*., 2005), suggesting that they could persist in *mtindi* fermented in field conditions also. Heat treatment of milk prior to souring would eliminate these pathogens, thus *mtindi* made from boiled milk rather than raw milk would be less likely to contain these pathogens.

A second major limitation of the VCRA (and related to the first) is the lack of microbiological evidence generated from the actual value chains under consideration to support the assumptions made in the risk assessment. Instead, these assumptions are informed by dairy value chain studies performed elsewhere. Both logistical and resource constraints precluded any laboratory work being undertaken as part of this research. This was not without its advantages; for example, we were able to foster closer, more trusting relationships with the value chain actors who participated in the research in part because taking samples of their milk/*mtindi* for testing was not part of our research protocol. In addition, we were able to dedicate more of the finite time available to us in the field to careful interviewing and observation, allowing us to unpick the various elements of the value chain strands more thoroughly. However, assessment of risk in the absence of microbiology is challenging. Whilst combining primary evidence from observation and interview/surveys with secondary evidence from other value chain studies was critical to inform the assumptions made in the VCRA with respect to the hazards and risks present, this did not equate to proof of a hazard or risk being present in the chains under consideration, as could have been demonstrated through microbiological work. Thus, in the absence of supporting microbiological evidence, the output of the VCRA remains somewhat speculative, and is hypothesis-generating in nature rather than confirmatory.

For example, in several areas of the VCRA, I made assumptions that the use of dirty water to clean equipment, or of visible dirt in the milk/*mtindi,* equated to an elevated infectious disease risk. However, there was no conclusive microbiological evidence to support this from our research; organic matter does not by definition contain infectious pathogens, and having unclean water or particles of soil mixed into milk or *mtindi* does not automatically render it unsafe for consumption. Although I drew from a wide range of literature which demonstrated that dairy value chains became increasingly contaminated with bacteria as chain length increased, no study attempted to disentangle to what degree that contamination was due to propagation of bacteria introduced at farm-level from milking compared to bacteria introduced further downstream due to poor hygiene and handling practices. This hindered my being able to make a more nuanced assessment of the relationship between visibly poor hygiene and infectious disease risk. Nonetheless, given that the World Health Organization estimates that some 10% of the Disability Adjusted Life Years (DALYs) in East Africa can be attributed to poor water supply, sanitation and hygiene (WASH), it is reasonable to assume that manifestly poor WASH conditions would elevate disease risk (World Health Organization, 2004).

A third limitation of the VCRA was that the risk assessment framework assessed impact by considering the volume of milk/*mtindi* disseminated by a particular actor and the number of actors to whom this milk/*mtindi* might be distributed. However, it did not take into account what proportions of milk/*mtindi* sold in Moshi Municipality were supplied by the different types of actor. Therefore, MCCs were assessed as high risk at bulking stage as they distribute milk to such a large number of clients, whereas intermediary traders were assessed as intermediate risk as they distribute less milk to a smaller number of clients. However, although it had proved challenging to generate accurate figures on proportional sales by the various value chain actors, it was clear that intermediary traders collectively sell far more milk in Moshi Municipality than do MCCs. Thus, although the purpose of a qualitative risk assessment is to help identify and prioritise particular risk areas (Thomas, 2013), nonetheless its interpretation can still be misleading without situating the risk assessment outputs in context.

Additionally, it can be argued that the VCRA is limited in scope. While the VCRA pays attention to the many bacterial pathogens that can be carried in milk and milk products, it fails to address the several non-bacterial food safety risks that can be posed by these products, risks which are also evolving and emerging as urbanization progresses. One such risk that is that of contamination of milk with mycotoxins, metabolites produced by filamentous fungi. Mycotoxins can cause a range of pathologies if ingested by humans, especially if consumed chronically. These pathologies include carcinogenicity, hepatotoxicity, genotoxicity, nephrotoxicity, reproductive disorders, immunosuppression and dermal irritation (Flores-Flores *et al.*, 2015). Several different types of mycotoxin have been demonstrated to be present in milk at varying levels as a result of dairy cattle consuming contaminated (i.e. mouldy) feeds (Flores-Flores *et al.*, 2015; Benkerroum, 2016).

The most well-studied mycotoxin known to affect milk is aflatoxin M1 (AFM1), produced by *Aspergillus* fungi; however, it is thought that different mycotoxins will likely coexist in foodstuffs and may cause synergistic effects, such that even if all are at nontoxic levels, together they could nonetheless cause toxicity (Flores-Flores *et al.*, 2015; Benkerroum, 2016). To date most studies have tended to consider specific mycotoxins in isolation, and more research is needed to ascertain their collective risks to human health (Benkerroum, 2016). While there remains a lack of systematically gathered evidence on the magnitude of mycotoxin contamination as a food safety issue, it is well recognised that concentrations of mycotoxins in milk in Africa, Asia and South America exceed those seen in Europe (Benkerroum, 2016). In their paper assessing the estimated global burden of aflatoxin-induced hepatocellular carcinoma, Liu and Wu (2010) noted that populations in developing countries in tropical and subtropical areas are nearly ubiquitously exposed to moderate to high levels of aflatoxin, as agricultural land in Africa and Asia lies in climatic regions favourable for *Aspergillus* proliferation, and suboptimal field practices combined with poor drying and storage conditions make crops vulnerable to fungal infection and aflatoxin accumulation. Indeed, a recent study found high proportions of milk samples collected from households in two counties in Kenya to be contaminated with AFM1 (Kang'ethe *et al.*, 2017).

As mycotoxins pass into the cow through ingestion of mouldy animal feed, cows that are zero grazed are more likely to be exposed than cows that are fed through fresh grazing systems (Kang'ethe *et al.*, 2017). As a consequence, urban cows may be more exposed to mycotoxin-contaminated foodstuffs compared to cows kept in rural areas where more grazing and fresh feeds are available, as demonstrated in a study from Kenya (Kang'ethe and Langa, 2009). Thus, although for bacterial pathogens it can be assumed that shorter urban-to-urban dairy value chains, where milk is both produced and sold in town, are safer for the consumer, this may not be true in relation to mycotoxicity, where milk produced in rural areas may be safer. Furthermore, while boiling milk can be said to eliminate most or all bacterial pathogens, the evidence surrounding whether heat treatment would reduce aflatoxins is ambiguous, with most studies to date suggesting not (Flores-Flores *et al.*, 2015). However, fermentation has been shown to inactivate mycotoxins in some cases, in which case *mtindi* might be considered the less risky product compared to boiled milk given that mycotoxins are thought to be heat stable – the converse of what would be considered to be true if considering bacterial pathogens only. Nonetheless, the extent of mycotoxin reduction due to fermentation has been shown to be highly variable depending on the nature and concentration of the of mycotoxins, and the types of *Lactobacillus* detoxifying strains present in the milk to begin with; i.e. the risk picture is complicated (Benkerroum, 2016).

Another non-bacterial health risk posed by milk is that of heavy metals. Milk contains essential minerals such as iron (Fe), zinc (Zn), and calcium (Ca); however, it may also be contaminated with some toxic heavy metals like cadmium (Cd), lead (Pb), arsenic (As), and mercury (Hg), which can cause various human pathologies including lung and blood cancer, kidney failure, osteoporosis, skeletal damage, gastrointestinal, and hormonal disorders, as well as some metabolic disorders including anaemia and excretory losses of enzymes and proteins (Ismail *et al.*, 2017). Once in the body, heavy metals bioaccumulate rather than being excreted. Children and the elderly are typically described as especially vulnerable to heavy metal exposure risks, making milk contamination a particular concern as these two groups tend to consume higher quantities of milk compared to the rest of the population (Tripathi *et al.*, 1999; Ismail *et al.*, 2017).

Heavy metals can come to be present in milk through a variety of routes. Cows may consume contaminated soil, grass or feeds and consequently excrete the metals in their milk (bioaccumulation is a particular problem in ruminants) (Pilarczyk *et al.*, 2013). Heavy metals in milk can also come from the containers used to store and transport milk; from the equipment used during processing; or through adulteration with contaminated water (Pilarczyk *et al.*, 2013; Zain *et al.*, 2016; Ismail *et al.*, 2017). While few studies have been carried out in East Africa to assess the extent of the problem in this region, globally a number of reports have shown elevated levels of Pb and Cd in milk and milk products, with contamination with Hg and As a lesser but still present problem (Ismail *et al.*, 2017). Urbanisation and industrialisation may be driving these risks: for example, heavy metals may enter into milk through contaminated animal feed by routes of irrigation with polluted canal or sewage water, the application of pesticides and fungicides, and the presence of industries near grazing areas (Ismail *et al.*, 2017). A study by Simsek *et al.* (2000) in Turkey that investigated the effect of environmental pollution on heavy metal content of raw milk found that heavy metal concentration was higher in milk from areas close to industrial zones and areas with significant vehicular traffic, and lower in milk samples from rural areas. Furthermore, as heavy metal contamination can occur through the equipment and machinery used in the processing and distribution of milk, some studies have shown that processed milk has higher levels of heavy metal contamination than raw milk (Kazi *et al.*, 2009; Lukáčová *et al.*, 2012). Thus again, the drivers of human disease risk due to milk contamination with heavy metals seem to conflict with those due to contamination with bacteria: when considering bacterial hazards, food safety recommendations would be to opt for short, urban-to-urban value chains where possible and to choose processed milk over raw milk, whereas the opposite may be true with regards heavy metals.

Antimicrobial residues (AMR) are increasingly recognised as a potential human health hazard found in milk. These residues may be present for two reasons: firstly because farmers have not observed an adequate withdrawal period after treating their animals with antimicrobials before selling their milk for consumption, or because antimicrobials have been added to milk at a later stage of the value chain in order to extend shelf life. Such residues may be the cause of numerous health concerns in humans, including toxic effects, transfer of antibiotic resistant bacteria to humans, immunopathological effects, carcinogenicity, mutagenicity, hepatotoxicity, reproductive disorders, bone marrow toxicity, and allergy (Darwish *et al.*, 2013).

A recent study in Tanzania found that a third of milk samples from farming households in three regions tested positive for tetracyclines or sulphonamides (Msalya, 2017), with several studies from Kenya finding similar results suggesting that AMR contamination may be widespread across the region (Ahlberg *et al.*, 2016; Ondieki *et al.*, 2017; Orwa *et al.*, 2017). Studies have also found milk produced in rural areas to have higher AMR concentrations than milk produced in urban or peri-urban areas, perhaps because animal health professionals are less accessible to advise on withdrawal periods (Aboge *et al.*, 2000; Kang'ethe *et al.*, 2005; Orwa *et al.*, 2017). There is also evidence of accumulation of AMRs along dairy value chains as they lengthen, due to bulking or to adulteration (Ahlberg *et al.*, 2016; Orwa *et al.*, 2017), although Kang'ethe *et al.* (2005) found in a study of marketed milk in Kenya that the less bulked the milk was, the higher the proportion of milk samples with detectable residues, perhaps because of dilution effects. In any case, the evidence suggests that as for bacterial disease risks, the risks posed by AMR will likely vary along dairy value chains and with different types of trader. AMR may also represent human health hazards in fermented milk products such as *mtindi* as they do in liquid milk. For example, a study from Nigeria which tested for penicillin residues in fermented milk, cheese and milk found no significant difference between the mean penicillin residues in all the dairy products tested (Olatoye, Daniel and Ishola, 2016). Furthermore, AMR in milk used to produce fermented products can interfere with the fermentation process by affecting desirable lactic acid bacteria. While this may simply represent a technical problem resulting in financial loss, it could also facilitate the growth of certain pathogens present in the milk and pose a health hazard in the finished product (Darwish *et al.*, 2013).

A final source of potential risk to human health from non-bacterial contaminants of milk is the addition of formalin or hydrogen peroxide to extend shelf life and improve product appearance and odour (Nascimento *et al.*, 2017). Formalin is highly toxic to humans in small amounts and is classified as a carcinogen. Ingestion is known to induce acute poisoning, causing irritation, dry skin, dermatitis, headaches, dizziness, tearing eyes, sneezing and coughing, and the development of allergic asthma (Handford, Campbell and Elliott, 2016). Hydrogen peroxide damages the gastrointestinal cells which can lead to gastritis, colitis, and bloody diarrhoea (ibid). There is little literature available on how widespread the practice of adulteration with these chemicals may be in East Africa, but media reports suggest it may be widespread (Gitonga, 2014; Anonymous, 2017). Nascimento *et al.* (2017) stipulate that hydrogen peroxide is one of the most common adulterants of milk, and a study conducted in 1999-2000 in Kenya reported that 2% of informal milk traders admitted to the practice (Omore *et al.*, 2001).

The potential presence of such a wide range of contaminants of milk in addition to bacteria demonstrates that it is important to think holistically when addressing food safety risks. Some phenomena driving infectious disease risks may also be driving non-infectious disease risks in parallel; for example, lengthening value chains leading to increased concentrations of both bacterial and AMR contaminants. However, some recommendations or interventions to improve food safety with respect to infectious diseases may have the unintended consequence of increasing non-infectious food safety risks, for example processing milk potentially increasing heavy metal contamination, or short urban-to-urban milk value chains driving mycotoxin contamination as urban animals are more likely to consume mouldy foodstuffs. The accepted wisdom of short value chains generally being safer for consumer health may therefore not hold true when considering a wider range of contaminants than infectious pathogens alone.

A final critique of the VCRA is that it is limited in scope precisely because its a priori approach is to use a disease lens which seeks to identify negative risks, rather than employing a holistic approach which recognises and incorporates the nutritional and socio-economic benefits that flow from participation in the value chain. The danger in this is that these "competing" beneficial elements are buried as a result of the foregrounding and privileging of food safety. In the consideration of proposed interventions and control measures to improve food safety, it is important to recognise who stands to lose as well as who could gain. For example, from a food-borne infectious disease point of view, it would seem sensible to recommend that all intermediary traders boil their milk prior to onward sale or conversion into *mtindi*, as this practice would serve to eliminate bacterial pathogens that had accumulated in the milk up to that point. A key tenet of food safety is to reduce bacterial contamination to its lowest levels possible at all stages in a value chain in order to ensure the final product reaching the consumer is as safe as possible. However, if we examine this recommendation in more depth, a more complicated picture emerges. Intermediary traders stand to lose if such a recommendation were to be enforced: boiling milk requires firewood, space, adequate equipment, and time, together amounting to a substantial outlay of resource for a population group who find the profitability of their trade precarious as it is. Moreover, handling large volumes of boiling liquid in environments not specifically designed for such a purpose poses a health hazard in itself. Given that consumers are highly likely to boil milk before consumption in any case, which would eliminate any bacterial risks present, is it questionable whether such a recommendation is as sensible as it may first seem.

On the other hand, as consumers cannot mitigate against potential infectious disease risks by boiling *mtindi* before consumption, a potential food safety recommendation could be that consumers should ensure that the *mtindi* they buy is made from fresh, boiled milk rather than raw or leftover milk. Such a recommendation may also have unintended negative consequences, however. This research has shown that *mtindi* is an important nutritional component of Moshi Municipality residents' diet; it has also shown that these residents are demonstrably concerned about food safety. In a context where consumers are currently unable to verify how the *mtindi* they purchase has been made, public health messaging that advises that residents should avoid certain types of *mtindi* out of concern for their health could potentially lead to people cutting this important source of nutrition out of their diet altogether, with the net effect on population health potentially being negative. This example underscores not just the importance of further, detailed work being carried out on the actual microbiological health risks posed by *mtindi* before making public health recommendations, but also how critical it is to ensure that the outputs of any VCRA are not simply taken at face value, but placed and interpreted in their broader context, employing true systems-wide thinking.

6.5 Conclusions

This chapter had a dual objective: to examine consumer knowledge, attitudes and behaviours related to the health risks of milk and *mtindi* consumption, and to systematically evaluate the probable infectious disease risks occurring along the milk and *mtindi* value chains supplying Moshi Municipality.

Our research found that consumers were well aware that dairy products could cause disease, with high levels of awareness of gastrointestinal illness and tuberculosis in particular. The practice of boiling milk before consumption was nearly universal, and the predominant rationale for pursuing this practice was to kill infectious microbes before consumption. Attitudes to the health risks of *mtindi* were more ambivalent; while consumption of raw milk was considered dangerous or even taboo, around 90% of frequent consumers of *mtindi* were unaware of whether the *mtindi* they consumed was made from raw or boiled milk. Exploring this apparent disconnect further did not reveal any dominant rationale as to why this was the case, although respondents' explanations and literature on the sociology of risk suggest that competing priorities (e.g. taste being more important than risk) might play a role, as might the desire to feel secure suppressing the desire to take action against risk; the lack of agency consumers had to protect themselves against risk; *mtindi* consumption not being linked to adverse health outcomes through personal experience; and *mtindi* being perceived as fundamentally different to milk and thus not posing similar risks.

The risk assessment identified bulking, wholesale and retail as hotspots for the introduction of infectious disease risk into both the milk and *mtindi* value chains. Milk and *mtindi* produced by urban livestock keepers in Moshi Municipality was estimated as posing the lowest infectious disease risks to human health, owing to their short temporal and spatial length and the very few numbers of value chain actors involved. However, even the longer, more complex rural-to-urban milk chains were assessed as posing low-medium risk to consumers owing to the widespread practice of boiling which would serve to eliminate viable pathogens in the milk. The highest risk to consumers was estimated to be posed by *mtindi* made using unsold milk, be it produced in town in the urban-urban chain or in rural surrounds in the rural-urban chain, based on the assumption that leftover milk would be highly contaminated with bacterial pathogens, and the fact that consumers could not mitigate the risk by boiling before consumption as they did for milk. Thus, evaluating the risks along the milk and *mtindi* value chains supplying Moshi Municipality has suggested that *mtindi*, particularly if produced from leftover milk, potentially posed the highest risk to consumers, even though it was the product for which consumers perceived the lowest health risks and for which it was difficult to take action to mitigate risk.

However, it must be stressed that the findings of this VCRA are in no way definitive: rather, they are hypothesis-generating in nature. Further research is needed to confirm the study results with biological sampling of pathogens at each step of the value chains and from each type of actor and each type of product involved (e.g. *mtindi* made from boiled versus raw, or fresh versus leftover milk) before firm conclusions can be made regarding the safety of the milk and *mtindi* consumed by Moshi Municipality residents. Our findings highlight a particular need for microbiological studies of *mtindi* to ascertain pathogen-specific levels of contamination and the potential bacterial health risks that may thus arise in association with consumption of this product.

Moreover, it should be borne in mind that this research considers infectious disease risk to consumers only. Conclusions may be different when considering a wider range of contaminants, such as mycotoxins, heavy metals or AMR. Food safety does not equate solely to the limitation of infectious disease risk, and both infectious and non-infectious contaminants should be considered holistically. However, there are inherent challenges in doing so given the limited evidence that has so far been collected in relation to these contaminants, and the lack of sophisticated methodologies and scientific technologies that would facilitate the risks posed by a wide range of potential contaminants to be considered together.

7 Discussion

7.1 Infectious disease risk along dairy value chains supplying Moshi Municipality: summary of the research findings

The global population is becoming rapidly more urbanised, with the fastest rate of urban growth occurring in East Africa (United Nations (UN) Populations Fund 2007; UN Dept of Economic and Social Affairs 2012; UN Human Settlements Programme 2008). As has been seen elsewhere, urbanisation is driving changes in food consumption patterns in this region, in particular increases in per capita consumption of animal source products (ASPs) (Popkin, 1994; Neumann, CG *et al.*, 2010; Steyn and Mchiza, 2014). While ASPs are an important source of protein and other nutrients, they are also a vehicle for food-borne zoonotic infections. Urban consumers may be at particular risk of food-borne disease (FBD) caused by these infections (Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016a). Not only can increased level of consumption be expected to correlate with increased level of exposure to food-borne infections, but long and complex livestock value chains supplying ASPs to urban consumers provide multiple opportunities for the introduction and propagation of bacterial pathogens along the chains, potentially heightening consumer risk (Rich *et al.*, 2011; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). The study of FBD risk to urban consumers in developing countries has been hampered by a lack of detailed data on patterns of urban food consumption, and by a lack of methodologies to systematically evaluate FBD risk in these settings (Grace *et al.*, 2008; Chan, 2014; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). This research aimed to contribute to these gaps in knowledge by investigating dairy product consumption in Moshi Municipality, an urban area of northern Tanzania, and developing and applying a value chain approach to assess the potential bacterial disease risks arising along the dairy value chains supplying these products and ultimately impacting on the final consumer.

The methodology for the research is described in Chapter 2. In brief, I developed a new conceptual framework for livestock value chains consisting of seven dimensions: input-output structure and geography (both *structural* elements of a value chain), governance, economics and knowledge (*functional* elements of a value chain); and non-human actants and adaptation (spanning both structural and functional elements of a value chain). I used a mix of interdisciplinary methods to investigate dairy consumption and acquisition patterns in Moshi Municipality, and to characterise the dairy value chains supplying the two most frequently consumed products, unpackaged milk and fermented milk (*mtindi*) to the town, as well as to document the risk activities occurring along them. For simplicity and ease of understanding, I considered each product as having its own separate value chain (i.e. rather than being considered as different channels of one overarching dairy value chain) with two distinct strands: a rural-to-urban strand and an urban-to-urban strand. This distinction depended on where the end-product (i.e. milk or *mtindi*) was produced. In the rural-to-urban strand, the end-product was produced in the rural surrounds of Moshi Municipality and brought into the town for sale. In the urban-to-urban strand, the end-product was produced in the town itself, i.e. for milk, from cows located and milked in town, and for *mtindi,* from milk fermented within the town (although the milk used for this process may have originated in rural areas). Using this collective information, I mapped specific risk pathways for the milk and *mtindi* value chain strands identified and applied a systematic qualitative risk assessment method along those pathways.

It is often assumed that urbanisation will drive changes in food choices in developing countries similar to those changes which have been seen in developed countries, with the result that urban diets in these countries become increasingly Westernised (Steyn and Mchiza, 2014). However, we found that two traditional dairy products, unpackaged milk and *mtindi*, were by far the products most frequently consumed by Moshi Municipality residents, and particularly so amongst population groups who were especially vulnerable to FBD, including children, the sick, the elderly, and postnatal mothers (Chapter 3). Frequency of consumption of unpackaged milk and *mtindi* increased as socio-economic status increased, whilst consumption of Westernised products such as packaged milk, cheese or yoghourt remained rare amongst all socio-economic groups. Our findings are consistent with other studies conducted in the region over the past two decades which also demonstrate that unpackaged milk and fermented milk products persist as preferred dietary staples, suggesting that a move towards increasing inclusion of packaged, pasteurised products in the diet as urbanisation progresses is neither rapid nor inevitable in these countries (Omore *et al.*, 2000; Njarui *et al.*, 2011; Akaichi, Chalmers and Revoredo-Giha, 2016; Haesler *et al.*, 2017).

These choices did not reflect a lack of awareness of or interest in the health risks and benefits of including dairy products in the diet. Moshi residents were highly motivated by health concerns when making dairy food choices, both in terms of what products to include and where to acquire them from. Consumers were well informed about many of the FBD risks posed by milk, and took active steps to mitigate these risks by boiling it before consumption (Chapter 6). However, this level of concern did not appear to extend to *mtindi*, which the vast majority of consumers consumed without knowing if it had been made from raw or boiled milk. Microbiological studies of fermented milk products are few, but suggest that several pathogens remain viable despite the low pH incurred in the souring process including *Salmonella* spp, *Staphylococcus* spp, *Listeria* spp, *Mycobacteria* spp, *Escherichia coli* spp and *Brucella abortus* (Ashenafi, 1993, 1994; Hempen *et al.*, 2004; Tsegaye and Ashenafi, 2005; Zúñiga Estrada *et al.*, 2005; Yilma and Faye, 2006; Yigrem and Welearegay, 2015; Knight-Jones *et al.*, 2016). Therefore, *mtindi* consumption may have posed a higher risk to consumers than milk, even though consumers perceived that the reverse was true. Further research involving biological sampling of pathogens present in the *mtindi* consumed by Moshi Municipality residents is required to confirm this hypothesis.

While there was some role for urban livestock keepers in supplying milk and *mtindi* to their communities directly, the milk and *mtindi* sold within Moshi Municipality predominately originated with milk produced by smallholder farmers in the rural regions surrounding the town. These spatially and temporally longer value chains can be expected to pose more of an infectious FBD risk to consumers compared to shorter chains involving fewer actors, as longer chains with multiple points of transaction and exchange provide more opportunities for pathogen introduction, as well as increased time for bacterial propagation (FAO, 2011; Rich *et al.*, 2011; Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). Numerous microbiological studies of dairy value chains in similar contexts have shown the levels of bacteria present in milk to increase as value chain length increases (Omore *et al.*, 2001; Grimaud, Sserunjogi and Grillet, 2007; Kilango *et al.*, 2012; Lubote, Shahada and Matemu, 2014; Doyle *et al.*, 2015; Joseph, 2015; Knight-Jones *et al.*, 2016). However, this is not to say that short value chains can be assumed to be risk-free, and again, further microbiological work is needed to investigate what bacterial hazards are present in the milk and *mtindi* consumed by Moshi Municipality residents, and at what levels.

Both the milk and *mtindi* value chains involved similar sets of value chain nodes and actors, with a large degree of overlap between the formal and informal sectors and little to no education and training on milk handling and hygiene for those participating in the chain (Chapters 4 and 5). Profitability was precarious and could lead to value chain actors practising behaviours which could potentially introduce infectious pathogens, such as adulterating milk with water. The existing legislation regulating the dairy industry was overly complex and neither recognised nor responded to the informal actors that predominated in the chains (Chapter 5). As a result, formal actors were over-regulated and ineffectively regulated, reducing their competitivity and allowing the unregulated, largely uninspected informal sector to flourish. This serves to exemplify how top-down legislation based on developed country standards can potentially impede rather than improve food safety by failing to reflect the context in which it will be implemented (Omore, Arimi and Kang'ethe, 2002; Omore *et al.*, 2011). In the absence of effective formal regulation, internal mechanisms of chain governance predominated, with systems of trust and social capital playing a vital role in both self-regulation and knowledge dissemination. This could work both for and against food safety. Actors' desire to preserve good relations with their suppliers and clients could both incentivise good hygiene and cleanliness, or give actors cause to not question potentially risky practices in the chain. Knowledge dissemination through social networks rather than through formal training allowed the potential for risk-heightening as well as risk-mitigating practices to spread and persist within the chains.

Systematic risk assessment suggested that the bulking, wholesale and retail stages were risk hotspots for the introduction and propagation of bacterial pathogens along both the milk and *mtindi* value chains. Bulking was a risk hotspot largely because of the mixing of large amounts of milk from many farmers in the absence of quality checks, and wholesale and retail largely because of the lack of cold chain and unhygienic conditions in which the products were marketed (Chapter 6). Urban livestock keepers tended to produce milk and *mtindi* in small quantities for sale directly to their neighbours, i.e. these were temporally and spatially very short value chains which involved none of the identified risk hotspots. Thus, these products were considered as posing the lowest infectious disease risk for consumers. Conversely, the rural-to-urban milk and *mtindi* value chain strands included all three hotspots and were therefore considered of higher risk to human health. Moreover, the practice of leaving unsold milk which had originated in the rural-to-urban strand to sour for sale as *mtindi* was identified as potentially further increasing consumer risk, as leftover milk would likely be highly contaminated with bacterial pathogens by the point of souring (Chapters 4 and 6). It should be noted that given that microbiological work was not part of the VCRA process, these results should be considered as hypothesis-generating rather than confirmatory. Further research involving biological sampling of the milk and *mtindi* sold and consumed in Moshi Municipality is required in order to validate the findings.

7.2 Implications for future research on infectious disease risks along dairy value chains in developing countries

The preference shown by Moshi Municipality residents for unpackaged milk and *mtindi* compared to packaged, pasteurised dairy products demonstrate that despite the diverse changes to food environments inherent in urbanisation, consumption of traditional ASPs can persist in the urban sphere. In East Africa, food policy is often modelled on industrialised country legislation, and subsequently there persists an attitude that public health regulations should discourage the sale of unpasteurised milk through informal milk markets (Mwangi *et al.*, 2000). This ignores the fact that consumers are well able to protect themselves (and do) from bacterial disease risks by boiling milk before consumption.

Our research has suggested that while raw milk undoubtedly poses infectious disease risks to consumers if not adequately heat treated before consumption, these may be outweighed by other risks that have generally been given less consideration: namely, those posed by consumption of *mtindi* and similar fermented milk products. Our findings have highlighted the lack of microbiological and epidemiological studies addressing the specific health risks posed by these products, despite their being widely consumed across the region (Haesler et al. 2017; Njarui et al. 2011; Melesse & Beyene 2009; Omore et al. 2002; Yigrem & Welearegay 2015). There is a clear priority for microbiological studies to ascertain what viable pathogens are present in *mtindi* at the point of consumption and in what numbers, and to investigate the impact that different production methods (boiled versus raw milk; fresh versus leftover milk) have on the type and degree of pathogen contamination present. Identifying microbiological hazards is just the first step, however. In order to relate these hazards to human disease, clinicians must take detailed food histories to ensure that associations between dairy product consumption and illness are captured, particularly given that symptoms of some dairy-borne diseases occur several weeks after exposure so patients may fail to self-report consumption (Table 1-1).

Producing *mtindi* from leftover milk, while potentially hazardous, is a crucial strategy for value chain actors to minimise spoilage losses. Such practice has also been noted in Zambia and is likely to take place in other countries in the region (Knight-Jones *et al.*, 2016). Finding means to valorise leftover products has been identified as a key strategy to minimise economic losses in tropical food chains, where informal markets often predominate with few mechanisms to calibrate supply and demand, and where foodstuffs perish quickly in the absence of cold chains and good hygiene conditions (van Tilburg *et al.*, 2007). The increasing length and complexity of livestock value chains serving urban centres is by now well recognised as a potential driver of infectious FBD risk to urban consumers (Food and Agriculture Organization, 2011; Rich *et al.*, 2011; Grace, 2015; Global Panel on Agriculture and Food Systems for Nutrition, 2016b). Our findings point towards another potential source of increased infectious FBD risk to urban consumers that until now has been overlooked: the practice of valorising unsold, potentially highly contaminated ASPs by converting them into alternative products for consumption.

It is difficult for consumers to distinguish between *mtindi* made from boiled or raw, or fresh versus leftover, milk. Promoting one type of *mtindi* over another for health reasons would be premature at this stage given the absence of rigorous microbiological and epidemiological evidence to underpin such recommendations, and could potentially cause unwarranted anxiety or even cause people to cease consuming a product important to their nutrition. Public health researchers and policy makers have a duty to ensure that all food safety recommendations are evidence-based. The evidence regarding the safety of informally marketed *mtindi* (and of similar fermented milk products consumed and enjoyed across East Africa) is, in the main, yet to be generated. This thesis identifies generating this evidence to be an urgent research priority.

7.3 Using value chain approaches as a methodology to evaluate FBD risk

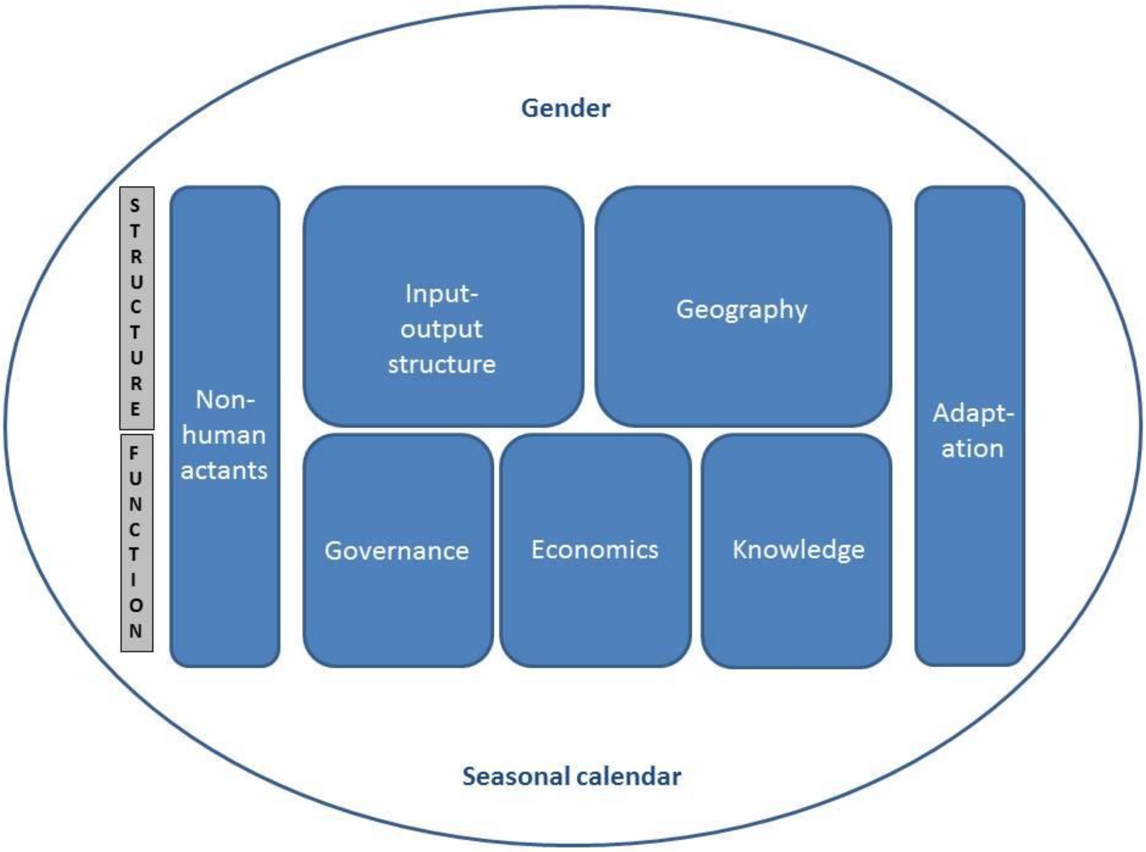
Much of the food trade in the developing world takes place within the informal sector. The absence of registration of value chain actors, of vertically integrated value chain nodes, of functioning legislation and regulation, and of records of livestock and ASP production and movements makes the implementation of the methodical systems of food safety risk assessment common to industrialised countries difficult (Grace *et al.*, 2008). In recent years, integrating value chain analysis with risk assessment approaches has been advocated as a methodology to address these challenges (Food and Agriculture Organization, 2011). The theory is that value chain analysis not only provides a structured framework within which a risk assessment can be conducted as a result of mapping the value chain, but can also provide information on the social, cultural, and economic factors which are driving these risks - factors which are usually unwritten and undocumented. In this section I discuss the strengths and challenges of using value chain approaches to evaluate FBD risk, first examining the conceptual framework I developed for this research and then offering a broader critique of value chain risk assessment (VCRA) as a methodological approach.

7.3.1 Evaluating the livestock value chain conceptual framework developed for this research

In order to conduct a VCRA of the dairy value chains supplying Moshi Municipality, I developed a conceptual framework for the analysis of livestock value chains which consisted of seven dimensions: input-output structure, geography, governance, economics, knowledge, adaptation, and non-human actants (Chapter 2 section 2.3). By applying this conceptual framework, I have produced a most detailed characterisation of a developing country dairy value chain as it pertains to disease, pollutants and risk. The in-depth contextualisation of the value chain strands provided information that was fundamental to the judgements I made concerning probability and impact along the risk pathways, and hence to the estimations of FBD risk, as well as helping to explain why those risks might be occurring. For example, information about the importance of trust and social capital along the value chain highlighted the disincentives to monitoring risk along the chain (e.g. by checking milk quality) as actors strived to maintain good relationships with suppliers. The consideration of non-human actants in the chain – a new addition to the value chain field – also generated important insights into drivers of risk that might otherwise have been missed. These include simple but powerful observations, for example that food grade equipment such as metal milk churns was unappealing to intermediary traders not just because of their cost or accessibility (although these both comprised barriers), but because their shape meant that they could not stack or attach to motorbikes well, severely limiting the quantities that traders could bring into town such that plastic buckets and jerry cans were preferred.

Having developed, applied, and analysed and reflected on the data that was generated by the conceptual framework, I believe that the framework can be improved in two key areas: consideration of gender and consideration of the seasonal calendar. When designing the framework, I intended to capture gender under the "horizontal elements" of the input-output dimension, and the seasonal calendar under the adaptation dimension. In hindsight I feel that these two areas merit attention as central issues in their own right, as each has the capacity to impact on all seven dimensions of the value chain. Therefore, for future ASP value chain analyses, I would modify the conceptual framework to that shown in Figure 7-1.

Figure 7-1 Revised conceptual framework for livestock value chain analysis



In Tanzania, women have traditionally played an important role in milk production and marketing, and have been able to decide how income from milk is spent; thus the benefits of participating in the dairy trade can flow disproportionately to women (Scanagari and Business Care, 2006; Grace *et al.*, 2008; Mchau *et al.*, 2009; Ministry of Livestock and Fisheries Development, 2011; International Livestock Research Institute and East Africa Dairy Development/Tanzania Dairy Survey, 2012). We found that women dominated at every stage of both the milk and *mtindi* chains, from the preponderance of women smallholder farmers to the women only co-operatives managing DPUs and MCCs, and the *Mama Lishe* street food vendors selling hot milk and *chai* (spiced milky tea) in town. Notably, women seemed to be more integrally involved in *mtindi* value chains than men. For example, market traders (who were invariably women) sold primarily *mtindi* and very little milk. In addition, it tended to be female intermediary traders who intentionally produced *mtindi* at their homesteads for sale in town, whereas male intermediaries reported that they only produced *mtindi* as a means of offsetting losses from unsold milk. Moreover, from a perspective of disease risk, the risk pathways associated with male and female value chain actors may have been different. For example, we found that female intermediary traders were less likely to have their own transport and would therefore sell their products in one location in town, compared to male traders who each had their own vehicles and could travel around the town to find customers. It could be hypothesised that increased travel along Moshi Municipality's dirt roads could lead to higher levels of product contamination, for example.

These gender differences support Grace *et al.* (2008)'s emphasis on the importance of considering gender in value chain risk analyses, particularly as proposed interventions might have broader societal implications through impacting on men and women differently. When designing the fieldwork, I believed it would be sufficient to take this into account by recording the gender of the value chain actors participating and considering this factor in the analysis. However, in practice this approach resulted in my only being able to make superficial observations regarding gender, such as those described above. I was unable to explore further what might lie behind those observations and what might stem from them, in particular the relationship between gender and FBD risk. The research could have been improved by integrating gender more explicitly into the research methods at the design phase, e.g. through conducting and comparing mixed-sex and single-sex group discussions with value chain actors, or using gender as a purposive selection criterion when recruiting participants to the study.

Kilimanjaro experiences its main wet season, the "long rains" from March to May, where the weather is generally cool. This is followed by a hot dry season from June to October and a period of "short rains" (where rainfall is lighter and less reliable compared to the long rains) from November to December. A short dry season from January to February precedes the long rains. The seasonal calendar impacted hugely on milk supply; in the rainy season when grass was plentiful, milk supply markedly increased. At the same time, roads in both Hai district and Moshi Municipality became difficult to negotiate owing to mud.

These changes reportedly impacted on who value chain actors could trade with; for example, a DPU might become inaccessible for a more remote farmer, or an intermediary trader might begin to reject milk from farmers once they had collected to maximum capacity. Milk would become harder to sell, with more left over at the end of the day and converted into *mtindi*. Supply and demand also affected prices, increasing in the dry season when milk supply could be scarce. These changes in the value chains would inevitably provoke changes in risk pathways and risk levels. I timed the fieldwork so that we would be in the field both as the dry season entered the short rains (first fieldwork phase, October to November 2013) and as the long rains entered the dry season (second fieldwork phase, April to July 2014). However, most of the value chain analysis was conducted during the rainy season, which lasted well into June that year. Therefore, information about activities during the dry season was usually reported rather than observed and thus less rich and potentially less reliable. Moreover, value chains were affected by other seasonal events not related to weather, such as Ramadan (when demand for milk reduced as many people were fasting) or school closure (when the market became flooded by milk that was usually sold to schools). Ideally therefore, value chain data should be captured year-round to ensure that the changes in value chain structure and function, and consequent changes in risk, are recorded first hand.

7.3.2 A critique of VCRA as a methodological approach to evaluate FBD risk

Value chains are, by their nature, complex entities. Even the relatively short, domestic dairy value chains examined in this thesis have been shown to encompass multiple actors who are interlinked by multifarious and idiosyncratic negotiated relationships which are continually influenced and modulated by multiple and often conflicting levels and layers of governance, economic pressures, and other factors. The theory and practice of value chain analysis advocates disentangling these complex realities in order to distil the key nodes, actors and relationships making up a value chain, in recognition that simplification can provide clarity of focus and aid in the understanding and explication of a complex world (Kaplinsky and Morris, 2000; Mccormick and Schmitz, 2001; Springer-Heinze, 2008; FAO, 2011). Kaplinsky and Morris (2000, pp24-25) note the power of value chain analysis as a heuristic tool, providing a framework that affords a better description of the world from which further data can then be generated. Manuals and toolkits for value chain analysis describe the need for researchers to first gain a broad-brush understanding of the value chain under investigation, and from there to focus down onto the particular value chain strands, issues, activities, and in the case of VCRA, risk practices, which are of interest. To present the results of the analysis, systems of organised, often linear flow-charts and maps are encouraged, at various levels of detail and with accompanying textual and quantitative data to aid contextual understanding (Kaplinsky and Morris, 2000; Mccormick and Schmitz, 2001; Springer-Heinze, 2008; FAO, 2011).

The danger of such an approach is that it can lead to outputs that are deceptively simplistic and thus potentially overlook or miss completely the wider implications of the messy complexity of value chains as they exist in the real world, together with the competing actors, interests and activities which are inherent in them. For example, for the purposes of this research I followed the guide of Mccormick and Schmitz (2001, page 47) that "*understanding the most important chains well is more important than attaining complete coverage*" and chose to focus only on the two most frequently consumed products, unpackaged milk and *mtindi,* rather than all of the various dairy products consumed by Moshi Municipality residents. For clarity, I considered unpackaged milk and *mtindi* as having separate value chains, rather than being strands of one complex dairy value chain involving several products. In order to delineate the different risk pathways, I also defined "rural-to-urban" and "urban-to-urban" value chain strands based on the location in which the end product (i.e. milk or *mtindi)* was made. In the manner advocated by value chain analysis theory, I produced simplified overview maps of the nodes and processes involved in the production of unpackaged milk and *mtindi* sold in Moshi Municipality (Figure 4-1 to Figure 4-4, Chapter 4) and of risk hotspots occurring along them (Figure 6-1 to Figure 6-6, Chapter 6), as well as textual data to accompany these maps (Chapters 4 to 6).

Taking this approach enabled me to focus on the two dairy products to which consumers had the highest level of exposure and thus likely had the most impact on consumers in terms of FBD. Considering the two products as having two separate value chains enabled me to disentangle strands of the milk and *mtindi* value chains that were highly intertwined, and from these to ascertain risk pathways that were specific to each strand and thus likely to pose different degrees of risk to consumers as a result of different risk practices and drivers of risk. For example, had I not used a value chain approach that scrutinised the input-output dimension of value chains, I may not have ascertained that *mtindi* was not just a single homogenous product, but rather could be made from fresh or leftover milk, or from boiled versus raw milk - each of which had the potential capacity to pose distinct risks to the consumer. This is a key finding which should inform the design of future studies investigating the food safety risks posed by fermented milk products.

However, the approach had its limitations. For example, considering milk and *mtindi* as having separate value chains obscured how interwoven the processes of production of the two foodstuffs were in practice. Largely the same processes and nodes were involved at each point, with value chain actors often producing or trading both unpackaged milk and *mtindi* alongside each other. This is not immediately obvious if the dairy value chain is presented as two separate value chains, rather than as different strands of one and the same chain. Similarly, the distinction obfuscates the fact that most “urban-to-urban” *mtindi* was really an extension of the rural-to-urban milk strand, produced as a means of valorising leftover milk of rural origin that had not been sold. The heuristic diagram representing the urban-to-urban *mtindi* chain (Figure 4-4), although easier for a reader to digest given its simplified format, disguises the many processes and activities that may have occurred before the diagram’s “start point”. The blurred distinction between point of milk origin and point of *mtindi* production could potentially give the reader the mistaken impression that this is always a short value chain. Thus, simplification cannot always be assumed to bring clarity.

Furthermore, choosing to focus only on unpackaged milk and *mtindi* effaced how and to what degree some value chain actors might “upgrade” their position in the value chain by opting to produce a wider range of products. This was particularly true for dairy processing units (DPUs), which produced a variety of packaged, processed products such as butter, cheese and yoghourt for retail in the tourist and affluent Tanzanian markets. This omission precluded an examination of the extent to which DPUs could utilise their ability to create and exploit alternative strands of the dairy value chain in order to counterbalance the difficulties they encountered in remaining competitive given the added costs of regulation and processing not faced by informal value chain actors.

In VCRA, the loss of relevant information resulting from efforts to simplify value chains in value chain analysis is compounded by similar efforts to simplify information in the risk assessment process. Qualitative risk assessment methodology proscribes that researchers should seek to describe defined risk pathways from “stable to table”, and to systematically interrogate each point of those pathways using specific risk questions, tabulating the relevant information openly and transparently, synthesising this information to determine informed estimates of probability and impact, and using pre-designed risk matrices to calculate risk at each point of the pathway based on these estimates (FAO, 2011). I followed this method in my research, using a risk pathway approach that integrated both the findings from value chain analysis with information about risk practices undertaken by value chain actors in order to qualitatively evaluate risk systematically for each pathway step. This enabled me to generate hypotheses about where and why infectious disease risk might be highest along the value chain strands and to present these risk hotspots as colour-coded visual diagrams that were simple to interpret (Figure 6-1 to Figure 6-6, Chapter 6). While the simplicity of this method is a strength, arguably it is also its weakness. The qualitative risk assessment process required me to assimilate a wealth of information and condense this into single judgments estimating probability and impact, a process that is necessarily subjective and undoubtedly biased according to the researcher making the judgement (Chapter 2). It was sometimes difficult to make those judgements: estimates could be contingent on context, for example the season under consideration. At times I felt as though I was forcing simplicity on a complex question.

Furthermore, the broad risk question I used (focussing on harmful bacterial pathogens generally rather than specific ones) could be a blunt tool. For example, it did not allow me to distinguish the different risks that would be posed by milk that had been heat treated and milk that had not. A series of pathogen-specific value chain risk assessments would arguably have been more insightful; however, at present there are few published epidemiological or microbiological dairy value chain studies in Tanzania to support this approach. Those that do exist tend to consider milk, not *mtindi*, and focus primarily on total bacterial counts (TBC) and/or total coliform counts (TCC) as an indicator of milk quality, rather than specific food borne zoonotic pathogens or taking FBD as the initial premise of the study (Kilango *et al.*, 2012; Shija, 2013; Lubote, Shahada and Matemu, 2014; Joseph, 2015). The lack of supporting scientific evidence is not only a challenge for dairy value chain research in Tanzania: the body of literature regarding zoonotic disease prevalence in low-income countries has been recognised as deficient both in volume and robustness, acting as an impediment to the support of zoonotic and food-borne risk assessments in these areas (Alonso *et al.*, 2016).

Lastly, both value chain analysis and risk assessment both tend to consider one particular issue, in the interests of simplicity, clarity and focus and to ensure that the findings are easy to understand and therefore impactful. As Mccormick and Schmitz (2001, p73) advise in their Manual for Value Chain Research, "*the power lies in simplicity and often this simplicity is best achieved if we deal with one issue at a time*." However, again this approach is somewhat siloed, and fails to recognise how the world consists of a series of overlapping systems, each of which affects the other. For example, this research considers bacterial disease risk only and does not address the many non-bacterial health hazards that can be present in milk products, which may pose different risks and require management measures that potentially conflict with those advised for infectious diseases (Chapter 6). Moreover, food safety is not the only nor even the primary consideration when it comes to the relationship between food value chains and human health and wellbeing; there are competing priorities than must be incorporated such as food security, nutrition, economics and poverty alleviation, and – particularly for the milk trade – gender equality and female empowerment.

Therefore, it is clear that while on the one hand, pursuing a VCRA methodology which seeks to simplify both value chains and risk questions can aid both project management and the generation of outputs that are easy to comprehend and are thus powerful in their messages, this very simplicity can be a shortcoming which frustrates the ultimate need to consider the multiple and conflicting FBD risks that exist in a real-world complex environment. New methodologies and scientific technologies that build on the VCRA approach but that can incorporate and simultaneously consider multiple contaminants and interwoven value chain strands need to be developed in order to address such complex questions fully.

In the meantime, when conducting VCRA it is important to look back in totality in order to see the complexity of the issues that the research process has uncovered. Value chain manuals tend to emphasise the importance of seeking a broad overview of a value chain first and then focussing in on a particular issue; however, less attention is given to the need to again “zoom out” towards the end of the research process in order to consider more analytically the wider implications of the research findings and how they are situated in their broader context. While VCRA is a powerful heuristic tool to identify and describe where and how FBD risk might be arising in a value chain, it is essential that the identified risk hotspots are not considered the primary results of the research. Rather, researchers must take an analytical approach, as advocated by Kaplinsky and Morris (2000) in order to consider the implications of their research findings as a whole. FBD risk is important, but it exists amongst a maelstrom of competing interests, priorities and systems. These must all be taken into account in the output of a VCRA, not least to assure that any recommendations surrounding proposed control measures or animal/human health policies to reduce FBD are proportionate and unlikely to have unforeseen negative impacts on other areas affecting human health and wellbeing. The next section embraces such an approach, and seeks to critically analyse current dairy policy in Tanzania in light of the more heuristic findings regarding dairy value chains and bacterial FBD risk described in Chapters 3 to 6.

7.4 Implications of the research findings with regard to dairy development policy in Tanzania

The policy environment governing Tanzania’s dairy industry is complex and comprises multiple pieces of legislation and policy covering dairy value chain governance of food safety. These policies have areas both of redundancy and conflict, and vary in the level to which the different policies are implemented (see Section 5.4.1 for more details). A review of all these policies is beyond the scope of this thesis; however, the 2015 Tanzania Livestock Modernization Initiative (TLMI) can be used as an exemplar of current aspirations for the future of the Tanzanian dairy industry. As a high-level summary document the Initiative does not include specific detail, but instead sets the tone and direction of livestock policy for the period 2015/16 – 2020/21 (Ministry of Livestock and Fisheries Development: United Republic of Tanzania, 2015).

The stated aims of the Initiative are to "*harness the potential of the meat, dairy and poultry sectors for poverty alleviation through improvements across the value chains*" with an overall goal to "*increase food and nutrition security and food safety, create employment opportunities and contribute to the national economy, social stability and sustainable environment*" (ibid, p9). In terms of development of the dairy sector, the Initiative sets forth a vision of providing pathways out of poverty through developing the commercial sector; increasing the number of improved breed cattle producing milk; investing in the set-up of more dairy hubs and processing units; and promoting the consumption of processed products amongst consumers. In so doing it builds on previous policies of formalisation of the dairy industry that were pursued in recent decades (see section 5.7). Taking into account the findings from the research we conducted into the dairy value chains supplying consumers in Moshi Municipality, I have identified three key areas in which the complexities of existing dairy value chains have not been fully recognised.

Firstly, the Initiative proposes a model of dairy development based on further commercialisation which, without recognition of the current context, may prove dysfunctional, ineffective or even detrimental. Our research found that the current governance mechanisms combine with basic infrastructure issues to create an environment in which processed dairy products are not likely to be competitive. The TLMI is based on the premise that investing in the commercialisation of the dairy sector will increase returns. However, we found little evidence to support this assumption; indeed, our findings suggest that, as a result of lack of consumer demand for processed dairy products, commercialisation may diminish returns rather than increase them. Nonetheless, it should be noted that we cannot make firm conclusions around the profitability of commercialising the dairy value chain as a whole as we only examined unpackaged milk and *mtindi*. The consumer hesitancy identified in this study around consumption of processed dairy products was in part due to concerns over food safety and health, with deep seated negative preconceptions and perceptions surrounding the safety and trustworthiness of "modern" farming methods. These reservations among consumers may prove hard to tackle solely by means of the national promotional and educational/information campaigns suggested in the Initiative. For these reasons, pursuing a policy of commercialisation and processing will likely only be effectively implemented if prior consideration is given to an appropriate transition process that recognises the large contribution and associated needs of the many informal value chain actors currently involved in the production, transport and sale of dairy products to Tanzanian consumers. At present there is no mention of these unregistered actors in the Initiative despite their major contribution to the current value chain.

A second limitation of the TLMI is its upstream-chain focus. The priority actions for the dairy industry are almost all targeted towards increasing milk production and organising smallholder farmers into business-oriented producer groups. There is virtually no mention of the many value chain actors downstream in the chain and the critical role they play in dairy product sale and consumer nutrition as the vital link between producers and consumers. Although the Initiative cites poverty alleviation and creating employment opportunities as primary objectives, it does not acknowledge the myriad employment opportunities that the dairy value chain creates in its current form, and how participation in the chain, whether it be in the formal or informal sector, is already forming a route out of poverty for both rural and urban Tanzanians, not just rural smallholder farmers. By overlooking this point, the Initiative appears to undervalue the status quo and does not consider the potential negative impacts of a policy drive that prioritises commercialisation of the chains, or who might stand to lose as a result of such a policy.

For example, the Initiative states that "*dairy…is considered one of the most promising agricultural pathways out of poverty and inclusive development given* *the control of milk production by women*" (Ministry of Livestock and Fisheries Development: United Republic of Tanzania, 2015, p20). While this may be true, we have seen in this research that participation of women in the dairy value chain is by no means limited to milk production: women predominate throughout the informal chain, as intermediary traders, market traders, and *Mama Lishe*[15], and the dairy value chain represents a pathway out of poverty and inclusive development for them, also. Concentrating investment in upstream chain upgrading and commercialisation not only ignores downstream value chain actors and the potential to create opportunities for their further development, but also risks excluding them from the dairy value chain entirely through increasing the level of competition with more formalised dairy businesses. Creating employment opportunities and alleviating poverty at one point in the chain may therefore occur at the expense of removing employment opportunities and exacerbating poverty at others. Careful consideration should be given as to whether such a policy would result in a net gain or loss for dairy value chain actors along the length of the chain, recognising the value of all the different types of actors fully.

Another group of value chain actors who could stand to lose from a policy of commercialisation is Tanzanian consumers themselves. The TLMI argues that about 180 million litres of marketed milk reaches consumption markets in the form of processed products, of which imports make up 60%, indicating a gap not being met by the domestic processing sector (Ministry of Livestock and Fisheries Development: United Republic of Tanzania, 2015, p21). However, our research suggested that the demand for processed products was chiefly from the tourist market, with the demand for such products by Tanzanians being low even amongst more affluent residents. It should be noted that we looked at consumption in Moshi Municipality only. However, if this pattern is repeated elsewhere in Tanzania, then a policy which advocates a shift towards processed products might have the unintended impact of decreasing the availability of unprocessed, unpackaged milk products for Tanzanian residents, with subsequent negative nutritional impacts that would potentially exacerbate

[15] Female street vendors cooking and selling simple meals and refreshments

health inequalities given that poorer Tanzanians may struggle to purchase more expensive, processed products.

The third weakness of the TLMI is in its limited coverage of food safety issues, despite food safety being identified as a key goal of the Initiative. While it is recognised that the TLMI, as a summary document, has little scope for detailed evaluation, attention to food safety is also only focussed upstream in the livestock value chain, concentrating mainly on investment in the provision of veterinary services to livestock keepers. There is little by way of consideration of FBD issues along a whole length of the food chain from “farm to fork” or “stable to table”, despite this being a key tenet of food safety theory and practice (Hathaway, 2013). In-keeping with this upstream approach, in the context of dairy value chains the TLMI document makes an implicit assumption that the key to ensuring consumer safety is to ensure that products are processed. However, our research findings have found this is not necessarily the case. Consumers of milk are able to protect themselves from common infectious health hazards present in unprocessed milk by boiling before consumption. This is not true though for all dairy products, such as *mtindi*, which is not boiled before consumption. Moreover, the assumption that processed products should be considered safe is questionable as products can be contaminated with infectious hazards after processing owing to inadequate storage, transport and sale conditions. There is little recognition in the TLMI of the degree to which basic infrastructure issues are currently impeding the assurance of food safety: unreliable or absent electricity supplies impeding chilling; poor quality roads impeding transport and facilitating product contamination; inadequate or unsanitary water supplies impeding proper cleaning of equipment; to name but a few. Where the Initiative does mention infrastructure, it does so in a manner that suggests that the changes that need to be made are specific to the dairy value chain and thus manageable, outlining a need to “*improve infrastructure for milk collection, handling, transportation and storage*” (Ministry of Livestock and Fisheries Development: United Republic of Tanzania, 2015, p21). It does not link these issues to challenges with high-level, national infrastructure, although it is difficult to see how any of these issues could be improved without addressing these broader challenges. Our research has suggested that national infrastructure issues such as road networks, electricity and water supplies are heavily contributing to FBD risk and will continue to do so whether products being retailed have been processed or not.

Thus, the results of this PhD thesis suggest that the strategy that the Tanzanian government is currently pursuing to further upgrade and develop the dairy value chain as articulated in the TLMI may struggle to succeed, both in terms of improving economic returns along the chain and in reducing FBD along the chain. In the case of economic returns, the proposed model of commercialisation and processing is constrained by enduring infrastructure and governance challenges that impede the competitivity of formalised value chain actors. However, it is encouraging to see that the TMLI acknowledges that the regulatory framework surrounding the dairy industry is currently dysfunctional and must be rationalised and reinforced – such measures could prove key to enhancing and resolving the competitivity of the formal sector. Nonetheless, the fact that there is also a low level of consumer demand for such products may also continue to limit the economic viability of this model. Pushing for upstream interventions and processed products as part of a dairy strategy to reduce FBD may be unsuccessful if other factors compromise food safety, for example rudimentary processing methods, poor roads, lack of a cold chain, and unhygienic market conditions.

Kaplinsky and Morris (2000, p38) stress that there are different modalities of upgrading a chain which must all be considered when formulating value chain development policy. The TLMI primarily focusses on what is termed *product* upgrading – developing the chain by introducing new products or improving old products; in the context of the TLMI, encouraging a shift towards packaged, processed dairy goods. However, while this is an understandable aspiration, longer term investment in infrastructure and governance is also needed before a model of formal actors selling processed products could achieve its potential, either in terms of economic success or food safety. Moreover, neither the informal dairy sector nor customer preferences favouring traditional, unprocessed dairy products are likely to rapidly disappear. Dairy development strategies are more likely to succeed if they recognise and respond to the current context rather than ignore or seek to supersede it through the imposition of “modern” technology and a more Westernised model. An alternative approach would be for the strategy to focus more on *process* upgrading, which seeks to increase the efficiencies of internal processes already existing within the chain. Our research findings have shown that there is already much that can be built on. For example, capitalising on the strong social networks and bonds of trust between informal traders could help spread knowledge and skills regarding hygienic milk handling and sale amongst these value chain actors. Previous studies have shown that simple training programmes aimed at informal value chain actors have been effective in improving the microbiological quality of the foodstuffs they trade (von Holy and Makhoane, 2006; Omore *et al.*, 2011). Tapping into consumer concerns for food safety could sensitise them to ask vendors for *mtindi* made from boiled or fresh milk (should microbiological evidence confirm that this is safer), preferences that would be communicated up the chain as traders are economically invested in pleasing their customers. While a strategy that responds to the current complex dairy value chain situation might be more complicated to develop and articulate, it is likely to be more successful in achieving its goals than one which opts to invest in the creation of increasing numbers of formalised dairy producer groups which then have to operate in a hostile environment. Collectively, the findings of the VCRA research detailed in thesis suggest that the TLMI's current approach to dairy development promises limited returns for the majority of Tanzanians either in terms of economics, nutrition, or food safety.

7.5 Conclusion

As urbanisation progresses rapidly in developing countries, food consumption patterns are changing and livestock value chains are becoming ever longer and more complex in order to satisfy increasing demands for ASPs in urban centres. The impact of these changes on food safety is largely unknown owing to the lack of empirical data on how diets are changing coupled with a lack of methodologies to evaluate FBD risk in developing country settings where food value chains are largely unregulated, informal, and shifting. This research aimed to help fill this gap by using a VCRA approach to investigate potential infectious disease risks occurring along dairy value chains supplying consumers in Moshi Municipality, a rapidly urbanising area of Northern Tanzania. In addition to the particular risks along the specific value chains identified in this work, the findings of thesis have identified some wider lessons for this research area.

Firstly, it cannot be assumed that urbanisation will drive changes in food choices in developing countries that are similar to those changes which have been seen in developed countries. Urbanisation does not inevitably lead to consumer preferences for Westernised products; rather, preference for traditional products may continue to persist. Neither can consumer concern for healthy foodstuffs be assumed to prioritise processed, packaged or “modern” products; indeed, the reverse may be true. However, consumers can and do take steps to minimise FBD risks where possible, but they do not always have the necessary knowledge or ability to do so. Along the journey from “stable to table”, different sections of a livestock value chain can be more or less risky, as can the practices of different groups of value chain actors active within a particular section. The practice of valorising leftover, unsold ASPs as alternative products for human consumption may represent a particular source of infectious FBD risk to urban consumers in developing countries.

VCRA can be a valuable heuristic tool to identify potential FBD risk hotspots in a livestock value chain and explain why these risks are occurring. However, inherent in applying this kind of methodology is a danger of oversimplifying a complex picture, and it is important to step back from the seemingly well-defined and straightforward outputs of a VCRA in order to situate those findings in their wider social, economic and political context. The detailed characterisation of a value chain that comes from doing VCRA means that as well as its use as a heuristic describing FBD risk, VCRA can also be a powerful analytical tool to evaluate, critique and develop livestock policy and strategy, highlighting potential pitfalls and identifying policy areas that need strengthening. By considering a livestock value chain in its totality and broader context, VCRA can identify elements of the chain that are working well and can offer constructive opportunities to be built on, rather than stopping at a description that serves mainly to paint the value chain as risky and wanting.

Nonetheless, the lack of robust microbiological studies along food value chains in developing countries remains a barrier to conducting risk assessments that are pathogen-specific and definitive rather than general and hypothesis-generating in nature. Furthermore, the usefulness of VCRA is hampered by its limited capacity to consider multiple FBD risks simultaneously. This includes both infectious and non-infectious disease risks, which may have competing or conflicting drivers (for example, longer rural-to-urban value chains leading to higher risk of infectious disease versus shorter urban-to-urban value chains leading to higher risk of mycotoxicity or heavy meatal poisoning). New scientific technologies that can identify multiple food contaminants, as well as new risk assessment methodologies that can contend with complicated systems of interwoven value chain strands simultaneously, are needed in order to fully address and explore the FBD risks arising from the complex and interacting dynamics that accompany value-added processes along food value chains.

Appendices

Appendix 1 – Ethics materials

1. Consumer survey consent form

University of Glasgow | College of Medical, Veterinary & Life Sciences

Participant unique identifier: ______________________________

CONSENT FORM

A survey of dairy product acquisition and consumption practices amongst urban and peri-urban consumers in Moshi municipality, northern Tanzania

funded by UK Medical Research Council Doctoral Training Programme, Research Code 60641; finance code 66397

Name of Researcher(s): Ms Georgia Ladbury; Prof Sarah Cleaveland; Prof Jo Sharp; Prof Rudovik Kazwala

Please initial box

I confirm that I have read and understand the information sheet dated __________ (version _____) for the above study and have had the opportunity to ask questions. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected. ☐

I agree to take part in the above study. ☐

Name of subject	Date	Signature/fingerprint
Name of Person taking consent (if different from researcher)	Date	Signature
Researcher	Date	Signature

(1 copy for subject; 1 copy for researcher)

College of MVLS Ethics Committee 1 January 2013 (lh)

2. Consumer survey information sheet

University of Glasgow | College of Medical, Veterinary & Life Sciences

Institute for Biodiversity, Animal Health and Comparative Medicine

A survey of dairy product acquisition and consumption practices amongst urban and peri-urban consumers in Moshi municipality, northern Tanzania

You are being invited to take part in a research study. Before you decide to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you wish to take part or not. If you decide to take part, you will be given a copy of the information sheet and a signed consent form to keep.

What is the purpose of the study?

In recent years, there has been a high level of migration to urban centres in Tanzania, and towns and cities are growing fast. Now that people are increasingly moving to live in urban and urbanising areas, their habits with regards what dairy products they consume, and where they acquire them from, are likely to have changed. These changes may have implications for health. This study aims to describe the supply of dairy products to residents of Moshi municipality. Specifically, we aim to understand what dairy products are consumed, how they are prepared, and where residents acquire them from.

The survey will run between October and December 2013.

Why have I been chosen?

Your ward was randomly selected from all of the wards in Moshi municipality for inclusion in the study. Your household was then randomly selected from all of the households in your ward. Our study requires one household member to answer on behalf of the whole household; preferably the female head of household should participate, but if that is not possible then the male head of household or other eligible adult (i.e. 18 years of age or older) can participate instead. We aim to recruit 145 households in total, some of which will also be in your ward.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you decide to take part in the research, you will be asked to complete a questionnaire which will be read out to you by one of the research team. Completing the questionnaire should take around 30 minutes. You may also be invited to participate in a longer interview (~1 hour) at a later date, where we would ask you more in-depth questions about the dairy products consumed in your household. However, even if you are invited to participate in such an interview, you are not obliged to do so if you do not wish to.

What do I have to do?

The study questionnaire asks about your ordinary dairy product consumption habits. There is nothing special that you have to do or change for this study.

What are the possible disadvantages and risks of taking part?

There are no foreseeable risks of taking part; however, completing the questionnaire will take about 30 minutes of your time.

What are the possible benefits of taking part?

You will receive no direct benefit from taking part in this study. The information that is collected during this study will give us a better understanding of how to improve the safety of dairy products supplying your area.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. You will be identified by an ID number, and any information about you will have your name and address removed so that you cannot be recognised from it.

What will happen to the results of the research study?

The results of the study will likely be published in an international scientific journal and presented at national or international scientific conferences. In addition, we will inform the executive officers of your ward and district of the study results.

Who is organising and funding the research?

The University of Glasgow is organising the research in collaboration with the Kilimanjaro Christian Medical Centre and the Sokoine University of Agriculture. The UK Medical Research Council is funding the research.

Who has reviewed the study?

The project has been reviewed by the College Ethics Committee of the College of Medical, Veterinary and Life Sciences, University of Glasgow.

Contact for Further Information

In Tanzania:

Ms Georgia Ladbury
0754866333
g.ladbury.1@research.gla.ac.uk

Prof Rudovik Kazwala
Sokoine University of Agriculture
PO Box 3000 Chuo Kikuu Morogoro

In the UK:

Prof Sarah Cleaveland
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Sarah.Cleaveland@gla.ac.uk

Prof Jo Sharp
00441413305405
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Thank you for your interest in our study

3. Consumer group discussion information sheet

University of Glasgow | College of Medical, Veterinary & Life Sciences

Institute for Biodiversity, Animal Health and Comparative Medicine

A study of the dairy products supplying urban and peri-urban consumers in Moshi municipality, northern Tanzania

We would like to invite you to participate in a group activity/discussion as part of a research study being undertaken by the University of Glasgow in the UK, in collaboration with Kilimanjaro Christian Medical Centre (KCMC) and Sokoine University of Agriculture (SUA). In recent years, there has been a high level of migration to urban centres in Tanzania, and towns and cities are growing fast. Now that people are increasingly moving to live in towns and cities, their habits with regard to what dairy products they consume, and where they acquire them from, are likely to have changed. These changes may have implications for health. The research study aims to describe the supply of dairy products to residents of Moshi municipality in terms of what dairy products are consumed, how they are prepared, and where residents acquire them from.

Your participation is entirely voluntary. If there is a question that you do not want to answer or an activity that you do not want to join in, you do not have to do so, and you are free to leave at any point without giving a reason and with no consequences to yourself. Any contributions that you make during the group work will remain anonymous in the research and your name will never be disclosed. If you wish any comments that you have made or information you have supplied to be deleted from the record, let us know and we will do so.

If you have any questions, please do not hesitate to ask us now. If you wish, we can also give you an information sheet with this information and the contact details of the researchers so you can contact us if you have any further questions in future.

Do you have any questions about the research?

Do you consent to participate in the study?

Contact for Further Information

In Tanzania:

Ms Georgia Ladbury
0754866333
g.ladbury.1@research.gla.ac.uk

Prof Rudovik Kazwala
Sokoine University of Agriculture
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Prof Jo Sharp
00441413305405
Jo.Sharp@gla.ac.uk

Thank you for your interest in our study

4. Information sheet for value chain actors

University of Glasgow | College of Medical, Veterinary & Life Sciences

Institute for Biodiversity, Animal Health and Comparative Medicine

A study of the dairy products supplying urban and peri-urban consumers in Moshi municipality, northern Tanzania

We would like to interview you as part of a research study being undertaken by the University of Glasgow in the UK, in collaboration with Kilimanjaro Christian Medical Centre (KCMC) and Sokoine University of Agriculture (SUA). In recent years, there has been a high level of migration to urban centres in Tanzania, and towns and cities are growing fast. Now that people are increasingly moving to live in towns and cities, their habits with regard to what dairy products they consume, and where they acquire them from, are likely to have changed. These changes may have implications for health. The research study aims to describe the supply of dairy products to residents of Moshi municipality in terms of where and how dairy products are produced, prepared, transported and sold to residents in the town.

Your participation is entirely voluntary. If there is a question that you are not comfortable to answer, you do not have to answer it, and you are free to leave at any point without giving a reason and with no consequences to yourself. Any comments that you make during the interview will remain anonymous and your name will never be disclosed. If you wish any comments that you have made or information you have supplied to be deleted from the record, let us know and we will do so. After the interview, if you agree, we may like to spend some time with you to observe the work you are doing in relation to dairy products. Again, your participation is entirely voluntary and you are free to end it at any point without giving a reason.

We may also wish to take a sample of your milk/mtindi for testing for various pathogens in the laboratory, for which you will be reimbursed. The results of these tests will only be published in group form and will not be traceable to you. Unfortunately, we will not be able to feed back your individual results, but we will inform your ward livestock field officer of the results of the study as a whole.

There is no payment for participation in the study, but if milk/mtindi samples are taken we will reimburse the cost of this at normal sale price.

If you have any questions, please do not hesitate to ask us now. If you wish, you can also keep this information sheet. It has the contact numbers of the researchers so you can contact us if you have any further questions in future.

Do you have any questions about the research?

Do you consent to participate in the study?

Appendix 2 – Index of research participants

1. Key informant interviews

- **First stage of fieldwork**

Date	Site	Ward/District	Present
25/10/2013	District Office	Moshi Municipality district	District Livestock Officer (Moshi Municipality) Head of Dairy Division (Moshi Municipality)
25/10/2013	Ward Office	Longuo ward, Moshi Municipality	Ward executive officer (Longuo) Livestock field officer (Longuo)
28/10/2013	Ward Office	Kiboriloni ward, Moshi Municipality	Ward executive officer (Kiboriloni) Livestock field officer (Kiboriloni)
28/10/2013	Ward Office	Mji Mpya ward, Moshi Municipality	Ward executive officer (Mji Mpya)
29/10/2013	Ward Office	Kiboriloni ward, Moshi Municipality	Ward executive officer (Miembeni) Ward executive officer (Majengo) Livestock field officer (Miembeni+Majengo)
30/10/2013	Ward Office	Kaloleni ward, Moshi Municipality	Ward executive officer (Kaloleni) Livestock field officer (Kaloleni) Street officer (sub-division of Kaloleni)
30/10/2013	Ward Office	Njoro ward, Moshi Municipality	Ward executive officer (Njoro) Livestock field officer (Njoro) Ward health officer (Njoro)
31/10/2013	Ward Office	Boma Mbuzi ward, Moshi Municipality	Ward executive officer (Boma Mbuzi) Livestock field officer (Boma Mbuzi) Ward executive officer (Pasua) Livestock field officer (Pasua)
31/10/2013	Ward Office	Korongoni ward, Moshi Municipality	Ward executive officer (Korongoni)
1/11/2013	Ward Office	Shirimatunda ward, Moshi Municipality	Ward executive officer (Shirimatunda) Livestock field officer (Shirimatunda)
8/11/2013	Sokoine University of Agriculture	Morogoro district	Chair, Tanzania Dairy Board

Second stage of fieldwork

Date	Site	Ward/District	Present
25/4/2014	District office	Hai district	District Agriculture and Livestock Development Officer (DALDO) Assistant to the DALDO District Veterinary Officer *NB district had no District Dairy Officer at time of interview*
29/4/2014	District office	Siha district	District Agriculture and Livestock Development Officer (DALDO) District Veterinary Officer District Meat Inspector *NB district had no District Dairy Officer at time of interview*
2/5/2014	District office	Moshi Rural district	District Veterinary Officer District Dairy Officer *NB district had no DALDO at time of interview*
8/5/2014	Ward office	Masama Mashiriki ward, Hai district	Ward livestock field officer (LFO)
8/5/2014	Village office	Ng'uni village, Masama Kati ward, Hai district	Village livestock extension officer (LEO)
12/5/2014	Ward office	Masama Magharibi ward, Hai district	Ward LFO
13/5/2014	Ward office	Machame Kaskazini ward, Hai district	Ward LFO Wari village LEO Foo village LEO
13/5/2014	Ward office	Machame Magharibi ward, Hai district	Ward LFO
14/5/2014	Snow View hotel	Boma Ng'ombe, Hai district	Programme Manager, Land O' Lakes

2. Consumer in-depth interview participants

Key identifier	Date	Ward	District	Age	Gender	Tribe
00LON02	15/11/2013	Longuo	Moshi Municipality	50+	F	?
00LON14	15/11/2013	Longuo	Moshi Municipality	50+	M	?
02MAJ21	22/11/2013	Majengo	Moshi Municipality	31-40	F	Chagga
01MIE08	22/11/2013	Miembeni	Moshi Municipality	18-30	F	Mngoni
02MAJ17	22/11/2013	Majengo	Moshi Municipality	18-30	F	?
03KAL18	29/11/2013	Kaloleni	Moshi Municipality	18-30	F	Pare
03KAL20	29/11/2013	Kaloleni	Moshi Municipality	31-40	M	Chagga
04MJI10+04MJI13	29/11/2013	Mji Mpya	Moshi Municipality	31-40, 31-40	F, F	Sambaa, Mmakonde
06PAS23	06/12/2013	Pasua	Moshi Municipality	18-30	F	Pare
08KOR21	12/12/2013	Korongoni	Moshi Municipality	31-40	F	Chagga
02MAJ19	20/12/2013	Majengo	Moshi Municipality	50+	M	Chagga
05BOM02	20/12/2013	Boma Mbuzi	Moshi Municipality	18-30	F	Mnyiramba

3. Consumer group discussion participants

Ward	Date	Group type	Respondent	Gender	Approximate age
Kiboriloni	31/10/13	Women's horticulture co-operative	A	F	40-50
10 members			B	F	40-45
			C	F	35-40
			D	F	25-30
			E	F	30-35
			F	F	40-50
			G	F	30-35
			H	H	35-40
			I	I	40-45
			J	J	40-50
Longuo	01/11/13	Specially arranged group	A	M	50-60
6 members			B	F	25-30
			C	F	20-30
			D	F	19-23
			E	F	20-25
			F	F	40-45
Korongoni	06/11/13	Specially arranged group	A	F	40-45
9 members			B	F	30-35
			C	F	25-30
			D	F	45-50
			E	F	40-50
			F	F	40-50
			G	F	45-50
			H	M	40-45
			I	F	30-35

Njoro Moshi 12 members	06/11/13	Bee-keepers' co-operative	A B C D E F G H I J K L	Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded Not recorded	50-60 30-40 40-50 50-60 50-60 40-50 50-60 40-50 50-60 50-60 40-50 60-70
Boma Mbuzi 7 members	07/11/13	Specially arranged group	A B C D E F G	M M F F F M F	40-50 30-40 25-30 30-35 40-45 40-50 35-40
Pasua 6 members	11/11/13	Specially arranged group	A B C D E F	F F M M M M	40-45 35-40 25-30 20-25 40-45 40-50

Majengo 16 members	15/11/13	Specially arranged group	A	F	25-30
			B	F	60-65
			C	F	45-50
			D	F	25-30
			E	F	25-35
			F	F	40-50
			G	F	40-45
			H	F	35-40
			I	F	35-40
			J	F	40-45
			K	F	35-40
			L	F	20-30
			M	F	40-45
			N	F	30-40
			O	F	20-25
			P	F	25-30
Mji Mpya 8 members	16/11/13	Women’s business co-operative	A	F	40-45
			B	F	30-40
			C	F	35-45
			D	F	30-40
			E	F	30-40
			F	F	45-50
			G	F	30-40
			H	M	20-30

4. Value chain actor participants

FAR = Smallholder farmer
ULK = Urban livestock keeper
MCC = Milk collection centre
DPU = Dairy processing unit
MKT = Market
IT= Intermediary trader
SHP = shop
Moshi Mun. = Moshi Municipality

Unique idenitifier	Value chain node	Gender	Village	Ward	District	Time Use	In-depth interview	Part. Obs.	VCRA survey
FAR-02-011	FAR	F	Wari	Machame Kaskazini	Hai	27/05/2014	27/05/2014	27/05/2014	-
FAR-02-012	FAR	F	Wari	Machame Kaskazini	Hai	28/05/2014	28/05/2014	28/05/2014	-
FAR-02-038	FAR	F	Wari	Machame Kaskazini	Hai	15/07/2014	15/07/2014	15/07/2014	-
FAR-03-016	FAR	F	Foo	Machame Kaskazini	Hai	18/06/2014	18/06/2014	18/06/2014	-
FAR-03-017	FAR	F	Foo	Machame Kaskazini	Hai	21/06/2014	21/06/2014	21/06/2014	21/06/2014
FAR-03-040	FAR	F	Foo	Machame Kaskazini	Hai	-	-	18/07/2014	18/07/2014
FAR-04-020	FAR	F	Nronga	Machame Magharibi	Hai	24/06/2014	24/06/2014	24/06/2014	-
FAR-05-024	FAR	F	Ng'uni	Masama Kati	Hai	-	-	30/06/2014	30/06/2014
FAR-05-026	FAR	F	Ng'uni	Masama Kati	Hai	02/07/2014	02/07/2014	02/07/2014	-
FAR-05-028	FAR	F	Ng'uni	Masama Kati	Hai	-	03/07/2014	03/07/2014	-
FAR-06-034	FAR	F	Mudio	Masama Mashiriki	Hai	11/07/2014	11/07/2014	11/07/2014	-
FAR-06-037	FAR	F	Mudio	Masama Mashiriki	Hai	-	-	12/07/2014	12/07/2014
FAR-07-999	ULK	F	?	Kiboriloni	Moshi Mun.	-	20/12/2013	20/12/2013	-
FAR-07-044	ULK	F	NA	Pasua	Moshi Mun.	-	-	-	21/07/2014
FAR-07-048	ULK	F	NA	Kaloleni	Moshi Mun.	-	-	-	23/07/2014
FAR-07-051	ULK	F	NA	Kaloleni	Moshi Mun.	-	-	24/07/2014	24/07/2014
FAR-07-052	ULK	M	NA	Majengo	Moshi Mun.	-	-	26/07/2014	26/07/2014
DCU-03-015	MCC	F	Foo	Machame Kaskazini	Hai	-	-	18/06/2014	18/06/2014
DCU-05-023	MCC	F	Ng'uni	Masama Kati	Hai	-	-	30/06/2014+ 04/07/2014	30/06/2014
DCU-05-025	MCC	F	Ng'uni	Masama Kati	Hai	-	-	01/07/2014	01/07/2014
DPU-03-014	MCC	M	Foo	Machame Kaskazini	Hai	-	17/06/2014	17/06/2014	-
DCU-05-027	MCC	F	Ng'uni	Masama Kati	Hai	-	-	02/07/2014	02/07/2014
DPU-02-007	DPU	F	Wari	Machame Kaskazini	Hai	23/05/2014	23/05/2014	23/05/2014	23/05/2014
DPU-04-019	DPU	F	Nronga	Machame Magharibi	Hai	24/06/2014	24/06/2014	24/06/2014	24/06/2014
MKT-VC019	MKT	F	NA	Kiboriloni	Moshi Mun.	-	24/4/2013+18/12/2013	18/12/2013	-
MKT-VC023	MKT	F	NA	Kiboriloni	Moshi Mun.	-	18/12/2013	18/12/2013	-
MKT-01-001	MKT	F	NA	Kiboriloni	Moshi Mun.	14/05/2014	14/05/2014	14/05/2014	-
MKT-01-009	MKT	F	NA	Kiboriloni	Moshi Mun.	25/06/2014	25/06/2014 + 21/06/2014	25/06/2014 + 21/06/2014	-
MKT-01-021	MKT	F	NA	Kiboriloni	Moshi Mun.	25/06/2014	25/06/2014	-	-
MKT-01-029	MKT	F	NA	Kiboriloni	Moshi Mun.	-	-	-	05/07/2014
MKT-01-041	MKT	F	NA	Kiboriloni	Moshi Mun.	-	-	19/07/2014	19/07/2014
MKT-01-042	MKT	F	NA	Kiboriloni	Moshi Mun.	-	-	19/07/2014	19/07/2014
MKT-01-053	MKT	F	NA	Kiboriloni	Moshi Mun.	-	-	30/07/2014	30/07/2014
MOB-VC021	IT	F	Foo	Machame Kaskazini	Hai	-	20/11/2013	24/04/2013	-
MOB-02-010	IT	F	Wari	Machame Kaskazini	Hai	26/05/2014	19/11/2013+26/05/2014	19/11/2013+26/05/2014	-

Unique idenitifier	Value chain node	Gender	Village	Ward	District	Time Use	In-depth interview	Part. Obs.	VCRA survey
MOB-VC021	IT	F	Foo	Machame Kaskazini	Hai	-	20/11/2013	24/04/2013	-
MOB-02-010	IT	F	Wari	Machame Kaskazini	Hai	26/05/2014	19/11/2013+26/05/2014	19/11/2013+26/05/2014	-
MOB-02-013	IT	F	Wari	Machame Kaskazini	Hai	28/05/2014	-	28/05/2014+30/05/2014	28/05/2014
MOB-02-043	IT	F	Wari	Machame Kaskazini	Hai	20/07/2014	-	20/07/2014	20/07/2014
MOB-03-018	IT	M	Foo	Machame Kaskazini	Hai	22/06/2014	22/06/2014	-	-
MOB-03-022	IT	F	Foo	Machame Kaskazini	Hai	27/06/2014	29/11/2013+27/06/2014	29/11/2013+27/06/2014	-
MOB-03-039	IT	F	Foo	Machame Kaskazini	Hai	17/07/2014	-	-	17/07/2014
MOB-06-030	IT	M	Mudio	Masama Mashiriki	Hai	08/07/2014	08/07/2014	-	-
MOB-06-031	IT	M	Mudio	Masama Mashiriki	Hai	08/07/2014	08/07/2014	-	-
MOB-06-032	IT	M	Mudio	Masama Mashiriki	Hai	09/07/2014	09/07/2014	-	-
MOB-06-033	IT	M	Mudio	Masama Mashiriki	Hai	10/07/2014	10/07/2014	-	-
MOB-99-035	IT	F	NA	Kiboriloni	Moshi Mun.	-	-	-	12/07/2014
MOB-99-036	IT	F	NA	Kiboriloni	Moshi Mun.	-	-	-	12/07/2014
SHP-VC001	SHP	M	NA	Longuo	Moshi Mun.	-	15/11/2014	-	-
SHP-VC045	SHP	M	NA	Mji Mpya	Moshi Mun.	-	29/11/2014	-	-
SHP-VC048	SHP	M	NA	Mji Mpya	Moshi Mun.	-	29/11/2013	-	-
SHP-VC050	SHP	M	NA	Pasua	Moshi Mun.	-	06/12/2013	-	-
SHP-VC051	SHP	M	NA	Boma Mbuzi	Moshi Mun.	-	06/12/2013	-	-
SHP-07-045	SHP	F	NA	Pasua	Moshi Mun.	-	-	-	21/07/2014
SHP-07-046	SHP	M	NA	Miembeni	Moshi Mun.	-	-	-	22/07/2014
SHP-07-047	SHP	M	NA	Majengo	Moshi Mun.	-	-	-	23/07/2014
SHP-07-049	SHP	F	NA	Njoro Moshi	Moshi Mun.	-	-	-	24/07/2014
SHP-07-050	SHP	F	NA	Miembeni	Moshi Mun.	-	-	-	24/07/2014

Appendix 3 – Data collection tools

1. Key informant interview schedule, Moshi Municipality

KEY INFORMANT INTERVIEW: [Ward] [Date]

Present:

INPUT-OUTPUT/GEOGRAPHY

1.Where does the milk coming into the ward come from?

- *Main milk-producing regions*
- *Smallholders*
- *Dairies*
- *Relative importance of each in terms of quantity?*

2. And where is it sold?

- *Shops*
- *Markets*
- *Cafes and milk bars*
- *Mobile traders*
- *School milk feeding programmes/other institutes*
- *Livestock keepers*

3. Relative importance of these outlets (in terms of quantity of milk/dairy products sold)?

4. Are there any producer/processor/consumer interest groups related to the dairy value chains that are active in this ward?

GOVERNANCE

3. Can you tell us a bit about the legislation and monitoring of the following in your ward:

4. Are there any certification schemes operating for people working in the dairy trade in your ward?

KNOWLEDGE

1.Are there any organisations that offer training to people involved in the chain in your ward?

ECONOMICS

1.Do you have a sense of the economic importance of the dairy industry in the ward:

2.Is the supply constant throughout the year?

CONSUMER KNOWLEDGE AND PERCEPTIONS

1.Do you anticipate that consumers living in this ward will consider milk and dairy products as an important part of their diet?

2.Have there been any public health/advertising campaigns in this area to encourage dairy product consumption?

3.Are consumers in Moshi district aware about safe storage and consumption of milk and dairy products?

CONTACTS

1.We would like to conduct some group discussions with consumers in your ward. Are there any existing community groups that we could visit for this purpose?

2. Consumer in-depth interview schedule, Moshi Municipality

Photos –

Date of visit: Street/Village:

District Subvillage:

Ward: Type of area:

GIS Co-ordinates:

E/W N/S: Altitude: Waypoint:

Check Dictaphone is working. Note down age/gender of respondent and general characteristics of the household.

Consumption patterns and practices

- Do you consider milk/ other dairy products important in your diet?
    - *Why?*
    - *How often do you consume them? Are they a luxury item or an everyday item?*
- Who consumes what dairy products in the HH?
    - *Is there a difference for men, women, girls, boys?*
- How do you consume these products?
    - *When do you eat/drink them? E.g. – with what meals, drinks?*
    - *How do you prepare them?*
    - *Ask for fresh milk, mtindi, cheese…etc.*
- Do the amounts of dairy products you consume vary during the year?
    - *When do you drink more/less?*
    - *Why?*
    - *Are there any special events when you consume more/different dairy products? (e.g. after childbirth, around Christmas time)*

Health and safety: knowledge and perceptions

- What are the benefits of consuming dairy products?
    - *If health isn't mentioned – ask if they believe that dairy products are good for their health, and why?*
- Are there any disadvantages of consuming dairy products?
- Do you think it's possible to get sick from eating or drinking dairy products?
    - *If yes – how can they make you sick (causes)?*
        - *what illnesses can they cause? what are the symptoms?*
        - *are there any ways you can prevent getting sick?*
- Do you boil your milk?
    - *If not, why not?*
    - *If yes – why? do you always boil it, or are there occasions when you don't?*

- Do you boil milk for making mtindi/mgando?
    - *If not, why not?*
    - *If yes – why do you always boil it, or are there occasions when you don't?*
- How do you store your dairy products?
    - *In what containers? What are the containers made of?*
    - *In what part of the house?*
    - *For how long?*
    - *Reasons for storing this way?*

Purchasing patterns

- How do you ensure that the dairy products that you consume are of good quality?
    - *And what about bad quality?*
- Where do you get your dairy products from?
    - *Ask for fresh milk, mtindi….etc*
- Do you usually go to the same place or vendor to get your dairy products?
- Why do you get dairy products from the places that you do? What factors help you choose where to get them from?

  e.g. taste; cost; trust; provenance; convenience; quality

- Where would you not get dairy products from? What factors would make you choose not to buy your dairy product from a particular place or trader?
- Do the prices of dairy product stay relatively stable throughout the year or does it change?
    - *What makes it change?*
- Does the supply of dairy product stay relatively stable throughout the year or does it change?
    - *What makes it change?*
- To your knowledge, where do the milk and dairy products that supply people in Moshi town come from?
- For the dairy products that you buy, do you know where the milk came from originally?

Value chain

- For our research, we'd also like to talk to people who produce or sell dairy products. Would you be able to tell us the location/contact details for where you buy your dairy products?

3. Consumer participatory piling exercise, Moshi Municipality

ICEBREAKING AND PARTICIPATORY PILING EXERCISE - CONSUMERS

Brainstorming/participatory piling exercise (45mins-1h). Sodas and snacks will be provided

1. First – get consent (verbal).

2. Start with introductions and gauge how long everyone has been living in the area, migration etc. *Optional – hand out bitings whilst introductions are going on.*

3. Introduce topic with pictures of what milk means to me from London: everyone sees milk differently and that's what we're here to talk about

4. Small groups (2-3): get everyone to think about the dairy products they consume (and what animal). After 5-7 minutes, write these on a large piece of paper that everyone can see; (if necessary invite someone to draw pictures if you sense that any group members might be illiterate)

5. Participatory piling exercise to work out what are the most frequently consumed products of those elicited in step (3)– i.e. what dairy products are most important. Consider the whole household, not individual so can catch children. Use 50 beans => %

e.g.

List the products elicited in step 3

	COW	SHEEP	GOAT
RAW MILK	••••••	••	
PACKAGED MILK	•		
MTINDI/MGANDO	•••••••••		
BUTTER	•••••	•	••
CHEESE	••		•••
CHAI	•••••••••••		

6. Ask whether there are any other dairy products that are consumed at specific times of year/special events; add these to the list if needs be.

7. Then ask if the frequency/amount of the top 5 dairy products they consume (elicited from previous exercise) changes dependent of the time of year/specific events? Consider the whole household, not individual so can catch children/post-partum mothers etc. Note down the responses.

8. In small groups as before (or brainstorming in a group if time is short), get everyone to list all of the places participants can obtain the top 5 products from – e.g. shop, market, make yourself, neighbour, street vendor, café…

9. Participatory piling exercise to assess what proportion of products are bought where

Top 5 products listed in step 5

	RAW MILK	MTINDI	CHAI	BUTTER	GOATS CHEESE
SHOP					
MARKET					
MAKE YOURSELF					
NEIGHBOUR					
STREET VENDOR					
CAFE					

10. Optional 15 minute break for soda and bitings prior to focus group discussion.

4. Consumer group discussion schedule, Moshi Municipality

GROUP DISCUSSION SCHEDULE: CONSUMERS

Check Dictaphone is working. Note down age/gender of each respondent and where they are sitting; assign each person a number so you can track who is speaking in the discussion. One person to facilitate discussion, other to take notes on who talks when and other dynamics in the group (e.g. nodding in agreement, gestures of dissent, etc)

Consumption patterns and practices

- Do you consider milk/ other dairy products important in your diet?
    - *Why?*
    - *How often do you consume them? Are they a luxury item or an everyday item?*
- Who consumes what dairy products in the HH?
    - *Is there a difference for men, women, girls and boys?*
- How do you consume these products?
    - *When do you eat/drink them? E.g. – with what meals, drinks?*
    - *How do you prepare them?*
    - *Ask for fresh milk, mtindi, cheese…etc.*
- Do the amounts of dairy products you consume vary during the year?
    - *When do you drink more/less?*
    - *Why?*
    - *Are there any special events when you consume more/different dairy products? (e.g. after childbirth, around Christmas time)*

Health and safety: knowledge and perceptions

- What are the benefits of consuming dairy products?
    - *If health isn't mentioned – ask if they believe that dairy products are good for their health, and why?*
- Are there any disadvantages of consuming dairy products?
- Do you think it's possible to get sick from eating or drinking dairy products?
    - *If yes – how can they make you sick (causes)?*
        - *what illnesses can they cause? what are the symptoms?*
        - *are there any ways you can prevent getting sick?*
- Do you boil your milk?
    - *If not, why not?*
    - *If yes – why? do you always boil it, or are there occasions when you don't?*
- Do you boil milk for making mtindi/mgando?
    - *If not, why not?*
    - *If yes – why do you always boil it, or are there occasions when you don't?*
- How do you store your dairy products?
    - *In what containers? What are the containers made of?*
    - *In what part of the house?*
    - *For how long?*
    - *Reasons for storing this way?*

Purchasing patterns

- How do you ensure that the dairy products that you consume are of good quality?
    - *And what about bad quality?*
- Where do you get your dairy products from?
    - *Ask for fresh milk, mtindi….etc*
- Do you usually go to the same place or vendor to get your dairy products?
- Why do you get dairy products from the places that you do? What factors help you choose where to get them from?
  e.g. taste; cost; trust; provenance; convenience; quality
- Where would you not get dairy products from? What factors would make you choose not to buy your dairy product from a particular place or trader?
- Do the prices of dairy product stay relatively stable throughout the year or does it change?
    - *What makes it change?*
- Does the supply of dairy product stay relatively stable throughout the year or does it change?
    - *What makes it change?*
- To your knowledge, where do the milk and dairy products that supply people in Moshi town come from?
- For the dairy products that you buy, do you know where the milk came from originally?

Value chain

- For our research, we'd also like to talk to people who produce and sell dairy products. Would you be able to tell us the location/contact details for where you buy your dairy products?

5. Consumer survey questionnaire

UNIQUE IDENTIFIER Cluster number [ ][ ] Ward (first 3 letters) [ ][ ][ ] Household number [ ][ ]

CONSUMER SURVEY QUESTIONNAIRE

A survey of dairy product acquisition and consumption practices amongst urban and peri-urban consumers in Moshi municipality, northern Tanzania

NB - This sheet contains personally identifiable information and must be removed and stored separately from the remainder of the completed questionnaire. Before doing so, ensure that the unique identifier is filled in on every sheet.

This questionnaire is designed to gather background data on milk acquisition and consumption by the 'household'. A household is defined as the group of people currently living in the same compound and sharing the same kitchen, where a compound is the bounded area/space directly around a dwelling (which may include other households).

Where possible, the female head of household should answer on behalf of the household; however, if she is not available then another household member (aged 18 years or over) can respond. Personal identifying data for the respondent will be recorded but will be stored separately from the rest of the questionnaire data.

GPS CO-ORDINATES

37M[_][_][_][_][_][_][_] UTM [9][6][_][_][_][_][_]

Elevation(m) [_][_][_][_] Waypoint ID [_][_][_]

Other comments to help identify household location (landmarks etc):

____

____

VISIT LOG

	Time (hh:mm, am/pm)	Date (ddmmyy)	Refused	Nobody eligible at home now	Not eligible	Absent	Consent
Visit 1							
Visit 2							
Visit 3							

NB – in case of non-inhabitation, not being a household or refusal to participate, replace with the next nearest household to the left (when standing with one's back to the main door of the household/building). In case of no answer or nobody eligible at home, return again (maximum two more times) at different times of the day/week, preferably including a Saturday where possible. If study enrolment is still not possible, replace the household as described above.

UNIQUE IDENTIFIER Cluster number | Ward (first 3 letters) | Household number

☐☐ ☐☐☐ ☐☐

INTERVIEW DETAILS - TAARIFA YA MAHOJIANO

Name of interviewer: ______________________________

Date of interview: ______________________________

Interview language: ☐ Swahili ☐ English ☐ Maa

Name and contact details of respondent: *(NB Fill this in at the end of the interview, only if the respondent has agreed to participate in further research)*

Name: ____________________ **Tel. number** (or other contact) ____________________

Preferred day/time for visit: ____

ELIGIBILITY - UHALALI

Before we start, I need to ask you: **Kabla hatujaanza napenda kukuuliza:**

E1 If unclear, Are you aged 18 years or over?

(Kama haileweki) Una miaka kumi na nane au zaidi?

YES ☐ Ndiyo *[Kama ndiyo nenda swali E3]* *If "Yes", skip to Question E3*

NO ☐ Hapana

E2 Is there anyone else in your household who is aged 18 years or over?

Je kuna mtu mwingene mwenye umri wa miaka kumi na minane na zaidi katika kaya yako?

YES ☐ Ndiyo *[Kama ndiyo zungumza na mtu anayefaa na uwanze tena mahojiano]*

[If "Yes", arrange to speak to an eligible respondent and begin questionnaire again]

NO ☐ Hapana **Ni bahati mbaya kuwa kaya hiyo haina vigezo kushiriki katika utafiti hii. Ahsante kwa muda wako. Kwaheri.**

If "No" to Questions E1 and E2-Unfortunately, your household does not meet the criteria required for this study.

E3 Have you been living at this address for the past six months or more?

Umekuwa ukiishi eneo hili kwa muda wa miezi sita iliyopita au zaidi?

YES ☐ Ndiyo *[Kama ndiyo nenda sehemu inayofuata]* *[If "Yes", skip to next section]*

NO ☐ Hapana

E4 Are there other people in your household who have lived here for the past six months or more?

Je kuna watu wengine walioishi kwenye kaya hii kwa miezi sita au zaidi iliyopita?

YES ☐ Ndiyo *[Kama ndiyo mhoji mtu aliyeishi pale zaidi ya miezi sita. Kama hawapo, basi uliza ni lini itakuwa muda msuri wa kurudi tena na uandike siku hiyo kwenye shajara yako]*

NO ☐ Hapana *Kama "Hapana" kwa E3 + E4-* **Ni bahati mbaya kuwa kaya hiyo haina vigezo kushiriki katika utafiti hii. Ahsante kwa muda wako.**

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

SECTION ONE - DEMOGRAPHICS

1.1. Jinsi ya mhojiwa Gender ☐ Me (M) ☐ Ke (F)

1.2. Je mhojiwa wa me/ke ni kiongozi wa kaya? Is the respondent the male/female HoH?

YES ☐ Ndiyo *[Nenda 1.4]* *[If "Yes", skip to 1.4]*

NO ☐ Hapana

1.3. Kuna uhusiano gani kati ya mhojiwa na mama wa kaya?(au baba wa kaya kama kaya ina wanaume tu)? What is the relationship between the respondent and the female head of the household (or male head in case of all-male household)?

____

1.4. Umri wa mhojiwa Age of respondent

☐ 18-30
☐ 31-40
☐ 41-50
☐ 50+

1.5. Kabila la mkuu wa kaya? What is the tribe of the head of the household?

☐ Chagga
☐ Para
☐ Maasai
☐ Sambaa
☐ Meru
☐ Mengineyo: ____________________

A household member is defined as anyone who is currently living at the household

1.6. Tafadhali kamilisha jedwali kuonesha ni wanakaya wangapi wapo katika kila kundi la umri (*Kwa kila kundi lenye watoto wa umri wa miaka 14 au chini ya hapo,tafadhali onesha idadi ya wanakaya katika kila kundi wanaonda shule)*

Please complete the table to indicate how many members of this household there are in each age group.
For the groups including children aged 14 years or less, please indicate the number of household members in each group that go to school.

	<5 years	5-9 years	10-14 years	15-17 years	18-30 years	31-40 years	41-50 years	50+ years
Idadi Number								
Idadi ya waoenda shule Number going to school						----	----	----

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

1.7. Je umeisha kwa muda gani katika kaya hii? How long have you lived in this household?

_____Miaka (YY) ______ Miezi (MM)

1.8. Je ni kwa muda gani wanakaya ambao ni watu wazima waliofika kwa muda wa karibuni wameishi katika kaya hii? How long has the most recently arrived member lived in this HH?

_____Miaka (YY) ______Miezi (MM)

1.9. Je ni kwa muda gani mwanakaya alieshi kwa muda mrefu ameishi katika kaya hii? How long has the longest residing member lived in this household?

_____Miaka (YY) ______Miezi (MM)

1.10. *(Kama ameishi katika kaya chini ya miaka 5):*

(If the longest residing member has lived at the household less than 5 years, where did the household come from?):

Je kaya imetokea wapi?

Kijijini/Mjini________________________________

Mikoa: ☐ Kilimanjaro ☐ Arusha ☐ Manyara

☐ Tanga ☐ Mikoa mingine____________________

1.11. Je kiwango chako cha elimu yako ni? How many years of education have you had?

- ☐ Hajasoma — No education
- ☐ Elimu ya msingi(1-7) — Primary (1-7 years)
- ☐ Elimu ya sekondari (Miaka 8-11) — Secondary (8-11 years)
- ☐ Elimuu ya juu — High school (12-13 years)
- ☐ Chuo kikuu — Elimuu ya juu

1.12. Je mwanakaya mwenye kiwango cha juu cha elimu ni kiwango gani? What is the highest number of years of education of any member of the household?

- ☐ Hajasoma — No education
- ☐ Elimu ya msingi(1-7) — Primary (1-7 years)
- ☐ Elimu ya sekondari (Miaka 8-11) — Secondary (8-11 years)
- ☐ Elimuu ya juu — High school (12-13 years)
- ☐ Chuo kikuu — Elimuu ya juu

1.13. Je unafanya kazi gani? What is your profession?

____

UNIQUE IDENTIFIER Cluster number ☐ ☐ Ward (first 3 letters) ☐ ☐ ☐ Household number ☐ ☐

SEHEMU YA PILI - MATUMIZI NA UPATIKANAJI WA BIDHAA ZINAZOTOKANA NA MAZIWA

SECTION TWO– DAIRY PRODUCTS CONSUMPTION AND ACQUISTION

2.1 Ni mara ngapi wanakaya katika kaya yako hula au hunywa mazao yafuatayo ya maziwa?

How often do you or any member of your household eat or drink the following dairy products:

	Kila siku Every day	*Kila wiki* Every week	*Kila mwezi* Every month	*Kwa nadra* Rarely	*Kwa matukio maalum (Bainisha tafadhali)* At a special event	*Kamwe* Never
2.1a Maziwa ya paketi Packaged (pasteurised) milk						
2.1b Mtindi ya paketi Packaged mtindi`						
2.1c Jibini, au Siagi ya makopo Packaged cheese, cream or butter						
2.1d Maziwa yaliochemchwa isiyo ya pakiti Boiled (unpackaged) milk						
2.1e Mtindi iliyotengenezwa kwa maziwa yaliyochemshwa Mtindi made from boiled milk						
2.1f Chai yamaziwa						
2.1g Maziwa mabichi Raw milk (not boiled nor pasteurised)						
2.1h Maziwa mabichi yanayongezwa kwenye vyakula vingine kama vile uji Raw milk added to other foods e.g. porridge (uji)*(i.e. the milk is still raw when consumed)*						
2.1i Jibini iliyotengenezwa kwa maziwa mabichi Cheese made from raw milk						
2.1j Siagi iliyotengenezwa kwa maziwa mabichi Butter made from raw milk						
2.1k Krimu iliyotengenezwa kwa maziwa mabichi Cream made from raw milk						
2.1l Mtindi iliyotengenezwa kwa maziwa mabichi Mtindi made from raw milk						
2.1m Mtindi, lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi Mtindi, not sure if the milk was raw or boiled/pasteurised						
2.1n Mazao mengine yaliotengenezwa kwa maziwa mabichi *Bainisha*________________________ ______________________________ Other products made from raw milk						
2.1o Jibini, Siagi, na bidhaa zingine lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi						

UNIQUE IDENTIFIER Cluster number | Ward (first 3 letters) | Household number

Cheese, butter, or other dairy product but unsure whether milk was raw or boiled/pasteurised						

2.2 Kati ya mazao uliotaja hapo juu ni ipi mwanakaya yeyote amekula/kunywa kwa muda wa siku saba iliyopita *[Kumbuka hili ni kwa mazao yale tu ambayo mhojiwa ajasema hawatumii kamwe]* Of the products you mentioned above, which have you or any member of the household eaten or drunk in the past seven days (*[NB Only read out products for which the respondent did not answer "Never" in the previous question]*

	Ndiyo (Y)				Hap-ana (N)	Sijui (DN)
	Ng'o mbe	Kondoo (Sheep)	Mbuzi (Goat)	Hakuna uhakika ni ya nini (Spp?)		
2.2a Maziwa ya paketi Packaged (pasteurised) milk						
2.2b Mtindi ya paketi Packaged mtindi`						
2.2c Jibini, au Siagi ya makopo Packaged cheese, cream or butter						
2.2d Maziwa yaliochemchwa isiyo ya pakiti Boiled (unpackaged) milk						
2.2e Mtindi iliyotengenezwa kwa maziwa yaliyochemshwa Mtindi made from boiled milk						
2.2f Chai yamaziwa						
2.2g Maziwa mabichi Raw milk (not boiled nor pasteurised)						
2.2h Maziwa mabichi yanayongezwa kwenye vyakula vingine kama vile uji Raw milk added to other foods e.g. porridge (uji)*(i.e. the milk is still raw when consumed)*						
2.2i Jibini iliyotengenezwa kwa maziwa mabichi Cheese made from raw milk						
2.2j Siagi iliyotengenezwa kwa maziwa mabichi Butter made from raw milk						
2.2k Krimu iliyotengenezwa kwa maziwa mabichi Cream made from raw milk						
2.2l Mtindi iliyotengenezwa kwa maziwa mabichi Mtindii made from raw milk						
2.2m Mtindi, lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi Mtindi, not sure if the milk was raw or boiled/pasteurised						
2.2n Mazao mengine yaliotengenezwa kwa maziwa mabichi Other products made from raw milk *Bainisha*______________________________ __________________________________						
2.2o Jibini, Siagi, na bidhaa zingine lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi						

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

Cheese, butter, or other dairy product, but unsure whether milk was raw or boiled/pasteurised						

2.3 Je ni kwa siku saba zilizopita ambazo umetumia mazao uliyotaja?

Was this a normal week for your household in terms of what food and drinks were consumed?

YES ☐ NDIYO

NO ☐ HAPANA Tofauti ni nini? ______________________

What was different?

2.4 Je kuna mazao mengine mnaotumia ambayo hayopo kwenye orodha iliyotajwa? If so, when/how often do you eat them? Kama ndiyo ni kwa mara ngapi mnakula bidhaa hizo?

Are there any other dairy products that you eat or drink that were not on the list mentioned?

____

____

2.5 Je kuna naykati maalumu za mwaka ambayo wanakaya katika kaya yako wanakula bidhaa hizo? *[Tia tiki panahuzika]*

Do you and your household members consume more dairy products in certain seasons of the year?

☐ Ndiyo-mengi wakati wa vuli — Yes-more in short rains O-D

☐ Ndiyo-Mengi wakati wa masika — Yes-more in the wet season M-M

☐ Ndiyo-Mengi wakati wa kipupwe — Yes-more in dry season J-S

☐ Ndiyo-mengi wakati wa kiangazi — Yes – more in the hot season

☐ Mengineyo (bainisha)______________________ — Other (please specify)

☐ Hapana — **No**

☐ Sijui — **Don't know**

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

2.6 Kwa kila bidhaa ambayo kaya yako inakula kila wiki au kila siku ni wapi haza mnazipata? *Tia tiki panapohuzika. Rejea jeduali 2.1 kwa bidhaa zinazoliwa kila wiki au kila siku]*

For the products that you/your household members eat every week or every day, where do you usually get them from? *[Tick all that apply. Refer to table in 2.1 for products eaten every week or every day]*

	Tunasalisha wenyewe Produce our own	Kwa wafugaji Local livestock keeper	Kwenye vituo vya maziwaa Milk centre	Wauzaji wadogowadogo wanatembeza /kuleta nyumbani Mob trader – delivered to house	Wausaji wadogowa dogo kwingineko Mobile trader - elsewhere	Sokoni Open market	Madukani Local shop	Duka kuu Super-market	Migawani/ mamalishe Café/bar/ restaurant	Sehemu nyinginezo—Bainisha Other – please specify
2.6a Maziwa ya paketi Packaged (pasteurised) milk										
2.6b Mtindi ya paketi Packaged mtindi										
2.6c Jibini, au Siagi ya makopo Packaged Cheese, cream or butter										
2.6d Maziwa yaliochemchwa isiyo ya Pakiti Boiled (unpackaged) milk NG'OMBE										
" " " " " " - KONDOO/MBUZI										
2.6eMtindi iliyotengenezwa na maziwa yaliochemshwa Mtindi made from boiled milk NG'OMBE										
" " " KONDOO/MBUZI										
2.6f Chai yamaziwa NG'OMBE										
" " " " " - KONDOO/MBUZI										
2.6g Maziwa mabichi Raw milk NG'OMBE										
" " " " " KONDOO/MBUZI										
2.6h Jibini iliyotengenezwa kwa maziwa mabichi Cheese made from raw milk NG'OMBE										
" " " " " " KONDOO/MBUZI										

UNIQUE IDENTIFIER Cluster number | Ward (first 3 letters) | Household number

	Tunasalisha wenyewe	Kwa wafugaji	Kwenye vituo vya maziwaa	Wauzaji wadogowadogo wanatembeza /kuleta nyumbani	Wausaji wadogowa dogo kwingineko	Sokoni	Madukani	Duka kuu	Migawani/ mamalishe	Sehemu nyinginezo—Bainisha
2.6i Siagi iliyotengenezwa kwa maziwa mabichi Butter made from raw milk NG'OMBE										
" " " " " " KONDOO/MBUZI										
2.6j Krimu iliyotengenezwa kwa maziwa mabichi Cream made from raw milk NG'OMBE										
" " " " KONDOO/MBUZI										
2.6k Mtindi iliyotengenezwa kwa maziwa mabichi Mtindi made from raw milk NG'OMBE										
" " " " " " KONDOO/MBUZI										
2.6l Mtindi, lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi Mtindi, not sure if the milk was raw or boiled/pasteurised NG'OMBE										
" " " " " " KONDOO/MBUZI										
2.6m Bidhaa zingine zilizotengenezwa kwa maziwa mabichi Other products made from raw milk *Bainisha* ______________________________ ______________________________ ______________________________										
2.6n Jibini, Siagi, Krimu, lakini huna wakika kama ilitengenezwa kwa maziwa yaliyochemshwa au mabichi Cheese, butter, cream or yoghurt but unsure whether milk was raw or boiled/pasteurised										
2.6o Mengine [yaliotajwa 2.4]										

UNIQUE IDENTIFIER Cluster number ☐☐ Ward (first 3 letters) ☐☐☐ Household number ☐☐

2.7 Je wana kaya katika kaya yako wananunua bidhaa hizo sehemu/muuzaji?
Do you/your household members usually get your dairy products from the same person/vendor?
Ndiyo ☐ (Y) Hapana ☐ (N) Sijui ☐ (DK) Haiusiki ☐ (N/A)

2.8 Je unajua chanzo ya maziwa inayotumika katika kaya yako?
Do you know which area the milk that you/your household members buy has originally come from?

NO ☐ HAPANA
YES ☐ NDIYO Wapi? ______________________________
Where?

SEHEMU YA TATU –AFYA NA USALAMA
SECTION THREE - HEALTH AND SAFETY

Ni kwa kiwango gani unakubaliana na sentensi zifuatazo?
How much do you agree with the following statements?

	Nakubali kabisa Strongly agree	**Nakubali** Agree	**Sina maoni** No opinion	**Sikubali** Disagree	**Sikubali kabisa** Strongly disagree
3.1 Bidhaa za maziwa ni sehemu muhimu katika mlo wa kaya yetu Dairy products are an important part of our household diet					
3.2 Bidhaa za maziwa ni nzuri kwa afya Dairy products are good for health					

3.3 Kuna jambo kaya yako inafanya kuandaa maziwa mabichi kabla ya kutumia? *[USICHOCHEE. Tia tiki panapohuzika]*
Is there anything that you or your household members do to prepare raw milk before consumption? Don't prompt. Tick all that apply.

☐ Kuchemsha — Boil it
☐ Kuchuja — Filter it
☐ Kuacha yagande — Leave it to sour
☐ Mengineyo — Other (please specify)
Bainisha tafadhali) ______________________________
☐ Hapana, tunayanywa maziwa hivyo hivyo — No, we consume the milk as it is
☐ Sijui — Don't know
☐ Hatutumii wala hatununui maziwa mabichi. — Not applicable – we don't use/buy raw milk

3.4 *[Nenda 3.7 kama mhojiwa amjibu hapana, sijui, haiuziki]*
Ni kwasababu gani mnafanya hivi? For what reasons do you do this?

____

____

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

3.5 Je kaya yako uwandaa maziwa mabichi kwa njia hii? Does your household prepare all raw milk in this way?

DK ☐ Sijui

Y ☐ NDIYO

N ☐ HAPANA

Tofauti yake ni nini? What are the differences?

____

____

____

____

3.6 Je kaya yako inandaa maziwa mabichi ambayo zinatumika kutengezea mtindi, jibini au siagi kwa njia hii? Does your household prepare raw milk that is used to make yoghurt, cheese or butter in this way?

DK ☐ Sijui

N/A ☐ Haihusiki *(hatutengenezi mtindi, jibini au siagi)*

Y ☐ NDIYO

N ☐ HAPANA

Kwanini hapana? Why not?

____

____

____

____

3.7 Ni kwa namna gani bidhaa za maziwa zinahifadhiwa katika kaya yako kabla hazijatumika? *[Kwa vyombo gani, kwa muda gani, seheumu gani ya nyumba, kwa maziwa freshi, mtindi….]*
How are dairy products stored in the household before eating/drinking them?

____

____

3.8 Ni kwa kiwango gani unakubaliana na sentensi zifuatazo?
How much do you agree with the following statement?

	Nakubali kabisa Strongly agree	**Nakubali** Agree	**Sina maoni** No opinion	**Sikubali** Disagree	**Sikubali kabisa** Strongly disagree
Bidhaa za maziwa zinasababisha magojwa Dairy products can cause illness					

UNIQUE IDENTIFIER Cluster number   Ward (first 3 letters)   Household number

3.9 *Iruke kama mhojiwa amekataa, amekataa kabisa katika maswali ya awali]*
Je unajua ugonjwa yeyote inayosababishwa na bidhaa za maziwa?
Do you know of any illnesses that milk or other dairy products can cause? *[Skip if the respondent answered "Disagree" or "Strongly disagree" to 3.8*

DK ☐ Sijui
N ☐ HAPANA
Y ☐ NDIYO

3.10 [Kama jibu ni ndiyo]   [If previous answer is YES]
Ni uganjwa gani inasababisha? *[Usichochee]*   What diseases can they cause?

____
____
____
____

SEHEMU YA NNE –UMILIKI WA MIFUGO NA MALI

SECTION FOUR - LIVESTOCK OWNERSHIP AND ASSET INDEX

4. 1 Je kaya yako inamiliki mifugo yoyote wakubwa?
Does your household own any adult livestock?

Aina Type	Idadi Number
Ng'ombe Cow	
Kondoo Sheep	
Mbuzi Goat	
Kuku Chicken	
Nguruwe Pig	
Mengine (Bainisha tafadhali) Other	

UNIQUE IDENTIFIER Cluster number ☐☐ Ward (first 3 letters) ☐☐☐ Household number ☐☐

4.2 Je wanakaya katika kaya hii wanamiliki vivyaa vifuatavyo?
Do the members of this household (all combined) own any of the following items?

Kifaa Item	**Hapana** No	**Sijui** Don't know	**Ndiyo** Yes
Baisikeli Bicycle			
Pikipiki Motorbike			
Gari Car			
Trekta Tractor			
Simu Mob tel			
Redio Radio			
Runinga TV			
Sofa Sofa			
Chandarua Bednet			
Friji Fridge			
Iron Pasi			
Akaunti ya Benki Bank account			

4.3 Je kaya yako ina: Does your household have:

	Ndiyo Yes	**Hapana** No	**Sijui** Don't know
Umeme Electricity			
Bomba la maji Tap water			

4.4 Je sakafu ya nyumba imetengenezwaje katika kaya yako?
Is the floor material in your household:

☐ Udongo Mainly earth
☐ Sementi Mainly cement
☐ Mengineyo Other
(Bainisha tafadhali)____
☐ Sijui Don't know

4.5 Ni aina gani ya chuo inayotumika katika kaya yako?
What kind of toilet facility do members of your household usually use:

☐ Chua cha kuflashi Flush toilet
☐ Chuo cha shimo Pit latrine
☐ Mengineyo Other
(Bainisha tafadhali)____
☐ Sijui Don't know

UNIQUE IDENTIFIER Cluster number | Ward (first 3 letters) | Household number

4.6 Katika wiki nne zilizopita mara ngapi yafuatayo yametokea?
In the past four weeks, how often has the following occurred:

	Kamwe Never	**Mara chache** Rarely	**Inatokeaga** Sometimes	**Kila mara** Always
4.6a Hakuna chakula cha aina chochote katika kaya yako There has been no food to eat of any kind in your household				
4.6b Ulienda kulala na njaa You have gone to sleep at night hungry				
4.6c Umeshinda siku nzima na usiku wote bila kula You have gone a whole day and night without eating				

UNIQUE IDENTIFIER Cluster number Ward (first 3 letters) Household number

NB - This sheet contains personally identifiable information and must be removed and stored separately from the remainder of the completed questionnaire. Before doing so, ensure that the unique identifier is filled in on every sheet.

SECTION FIVE– VALUE CHAIN CONTACTS AND FUTURE RESEARCH

5.1 Kama inawezekana, unaweza kutupatia taarifa ya watu/mahali ambayo unanua bidhaa za maziwa? If possible, could you please provide us with contact details for the people or places where you get your dairy products?

MUUZAJI 1

Jina_______________________ Aina ya muuzaji_______________________

Mahali________________________________

Mawasiliano___________________________

Kama inusika ataje muda anaouza maziwa (muda, siku ya wiki)

____

Wet season Masika ☐ Dry season Ukame ☐ Both Zote ☐

MUUZAJI 2

Jina_______________________ Aina ya muuzaji_______________________

Mahali________________________________

Mawasiliano___________________________

Kama inusika ataje muda anaouza maziwa (muda, siku ya wiki)

____

Wet season Masika ☐ Dry season Ukame ☐ Both Zote ☐

VENDOR 3 MUUZAJI 3

Jina_______________________ Aina ya muuzaji_______________________

Mahali________________________________

Mawasiliano___________________________

Kama inusika ataje muda anaouza maziwa (muda, siku ya wiki)

____

Wet season Masika ☐ Dry season Ukame ☐ Both Zote ☐

UNIQUE IDENTIFIER Cluster number | Ward (first 3 letters) | Household number

5.2 Kama inawezekana, unaweza kutupatia taarifa ya mahali ambayo huwezi kukunua bidhaa za maziwa? *Tafadhali wajulishe wahojiwa kuwa majina yao yatatunzwa kwa siri kubwa]* If possible, could you please provide us with details of places where you prefer *not* to buy your dairy products?

MUUZAJI 1

Jina_____________________________ Aina ya muuzaji ____________________________

Mahali____

Mawasiliano__________________________________

Kama inusika ataje muda anaouza maziwa (muda, siku ya wiki) ____________________________

MUUZAJI 2

Name Jina_____________________________ Type of trader Aina ya muuzaji____________________________

Location Mahali____

Contact details Mawasiliano__________________________________

If applicable - Time when selling milk Kama inusika ataje muda anaouza maziwa (time, day of week muda, siku ya wiki)____________________________

5.3 Je utapenda tukutembelee tena kwa mahojiano zaidi kuhusu utafiti hii? Kwa mfano kuhojiana kwa kwa kina jinsi kaya yako inavyochukulia bidhaa za maziwa? Would you be happy for us to visit you again for further studies related to this research, e.g. an in-depth discussion on how your household views dairy products?

☐ NDIYO *[Kama ndiyo jaza majina na mawasiliano katika kurusa ya pili ya hojaji hili na uwaulize kama kuna muda wanaopendelea kupangwa ratiba ya kuwatembelea tena]*

☐ HAPANA

TUNASHUKURU SANA KWA KUKAMILISHA MAHOJIANO YETU. TUNADHAMINI MUDA WAKO. UWE NA ASUBUHI/MCHANA/JIONI NJEMA

6. Example of value chain risk survey tool – farmer

VALUE CHAIN RISK ANALYSIS CHECKLIST - FARMER

Date		**Info gleaned by:**		**Demographics**	
Unique identifier		I-D Interview		Gender	
Village/sub-village		Part. observn		Age	
Ward		Rapid survey		Tribe	
No/ milking cattle:		TUA		Education level	
Breed of cattle:				HH size (adults, M:F)	
				HH size (<18, M:F)	

PRODUCTS SOLD

	Tick	Boil -ed?	Amount prod./ day	Amount sold /day	Amount pr /d, dry season	Amount sold /d, dry season	Price per litre now	Price / litre dry season
Fresh milk								
Mtindi								

CUSTOMERS

	House-hold use	Neighbour		Mobile trader		Urban market		Dairy processing unit		Other (specify)	
	Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres
Now											
Dry season											

INFRASTRUCTURE

	Tick	Comments e.g. reliability
Electricity		
Water supply		

ENVIRONMENT	Comments
Holding area • Description of structure (roof, coverage, floor, slope, drainage, bedding) • Cleanliness; ease to clean; C&D procedures • Accumulations of manure? • Rodents – presence + control measures • Flies etc • Other animals • Suitability (e.g. drainage, risk of udder diseases/teat injuries) • Other structures nearby e.g. feed pile, manure heap?	

HYGIENE SCORE: 1-5 ________ (1=very poor, 2=poor 3=satisfactory, 4=good, 5= very good)	
Milking area • Separate from holding area? • Description of structure (roof, coverage, floor, slope, drainage) • Cleanliness; ease to clean; C&D procedures • Accumulations of manure? – fresh/dry • Rodents and other animals • Lighting • Ventilation • Dust • Flies etc. • Water supply? Potable? • Separation from other sources of contamination e.g. manure heap **HYGIENE SCORE: 1-5 ________** (1=very poor, 2=poor 3=satisfactory, 4=good, 5= very good)	

VALUE CHAIN RISK ANALYSIS CHECKLIST - FARMER

ANIMAL HEALTH	
• Actions if cow is sick, inc. what happens to milk • Isolation of sick cow(s) possible? • Veterinary drugs • Vaccinated? • Knowledge of zoonoses	
MILKING PROCEDURE	
Time of milking **Milker hygiene** • Clean clothes • Short sleeves • Handwashing • Smoking/coughing/sneezing **Animal hygiene** • Cleanliness/manure soiling udders, teats, groin, flanks, abdomen • Udder cleaned before milking? • Udder dried before milking? • Teat lubricant	

Milking procedure • Foremilk stripped and discarded? • Touching of dirty areas then udder? • Organoleptic tests of milk? • Sick animals milked last? • Any dust-generating activities before/during milking e.g. feeding, cleaning? **Equipment** • For restraint; vessel used to wash udder; milking pail; udder cloths; milk strainer • Material • Cleanliness + ease to clean; C&D procedures • Covered? • Scooped or poured?	
HANDLING AND STORAGE	
Equipment • Material + provenance • Cleanliness + ease to clean; C&D procedures • Can equipment drain fully? • Covered? • Scooped or poured? **Location stored** • Temperature • Refrigerated? Electricity? • Vermin? **Time stored till sold to customers** **Onward transport for sale** *[if applicable]* • Vehicle + containers • Temperature + time	

TRAINING AND KNOWLEDGE	
From whom? Frequency? Animal health + use of veterinary drugs Hygienic milking Handling and storage Knowledge of zoonoses	
MISCELLANEOUS	
Why DCU/DPU rather than other customers (or vice versa) Challenges Pride	

7. Example of value chain risk survey tool - dairy processing unit (DPU)

VALUE CHAIN RISK ANALYSIS CHECKLIST – DAIRY PROCESSING UNIT

Date		Is plant at capacity?		**Info gleaned by:**	
Unique identifier		No. Staff (M:F)		I-D Interview	
Village/sub-village		Age of respondent		Part. observn	
Ward		Gender of respdt		Rapid survey	
Year plant started		Role at DPU:		TUA	

PRODUCTS SOLD

– Are there written records for this ? ***Y / N***

Timeframe: ***per day / per week / per month***

		Total	Super-markets		Shops		Cafes		Mobile traders		Market traders	
Product		Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres
	Now											
	Dry seasn											
	Price(w-d)											
	Now											
	Dry seasn											
	Price(w-d)											
	Now											
	Dry seasn											
	Price(w-d)											
	Now											
	Dry seasn											
	Price(w-d)											
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	Dry seasn											
	Price(w-d)											
	Now											
	Dry seasn											
	Price(w-d)											
	Now											
	Dry seasn											
	Price(w-d)											

		Local HH		Urban HH		Other		Other		Other		Other	
Product		No.	Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres	No.	Litres
	Now												
	Dry seasn												
	Price(w-d)												
	Now												
	Dry seasn												
	Price(w-d)												
	Now												
	Dry seasn												
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	Price(w-d)												
	Now												
	Dry seasn												
	Price(w-d)												
	Now												
	Dry seasn												
	Price(w-d)												

Notes:

SUPPLIERS (from whom milk is purchased)

	Smallholders		Intermediary traders		Dairy collecting unit (specify)		Other (specify)	
	No.	Litres	No.	Litres	No.	Litres	No.	Litres
Now								
Dry season								
Price								
Comments e.g. part of a collective?								

FLOOR PLAN

Include movement directions for people and products

VALUE CHAIN RISK ANALYSIS CHECKLIST – DAIRY PROCESSING UNIT

INFRASTRUCTURE AND LAYOUT

	Comments e.g. reliability
ELECTRICITY	
WATER SUPPLY Potable? Supply + storage Contam by pests possible?	
BUILDING **Location** • Near polluted areas? • Subject to flooding? • Area where wastes cannot be removed effectively? **Layout** (refer to floor map) • Movements (one way?) • Drainage • Handwashing facilities • WC **Structural integrity** **Lighting** **Air quality + ventilation**	
SURFACES, STRUCTURES AND FITTINGS **Cleanliness; ease to clean; C&D** • Floors • Work surfaces • Shelves • Equipment e.g. materials, smoothness, does positioning allow access, is drainage adequate, durability	
PESTS **Access and control measures** • Insects – window screens? • Rodents • Birds • Other animals	

VALUE CHAIN RISK ANALYSIS CHECKLIST – DAIRY PROCESSING UNIT

COLLECTING PROCEDURE	
Mode of transport • How are milk/products brought to trader? • Vehicle • Cold chain • Contaniers **Handling** • Are milk/products mixed? • Scooping or pouring? • Hand washing? • Clean clothes? • Smoking? **Equipment** • Material + provenance • Cleanliness + ease to clean; C&D procedures • Covered?	
PROCEDURE FOR RECEIPT OF MILK	
Time of day **Reception area** **Speed of reception** **Quality tests?** • Organoleptic • Ethanol • Clot on boiling • Lactometer • Temperature • Sanctions if poor quality **First arrived first processed?**	

HEAT TREATMENT PROCEDURE	
Equipment Time + temperature control Cleanliness, ease to clean, C&D procedures Maintenance	
COOLING PROCEDURE	
Handling - hygiene Equipment Time + temperature control Cleanliness, ease to clean, C&D procedures Maintenance	

PACKAGING	
Where is the packaging kept? **Quality + state of packaging** **Machinery + equipment** **Cleanliness; ease to clean; C&D**	
HANDLING AND STORAGE	
Location stored • Refrigerated? Electricity? • Vermin? **Containers/equipment** • Material + provenance • Cleanliness + ease to clean; C&D procedures • Can relevant equipment drain fully? • Covered? • Scooped or poured? **Time stored** **Temperature** **Staff hygiene** • Personal cleanliness and protective clothing • Handwashing • Behaviours – smoking, eating, chewing sneezing etc • Illness	
TRANSPORT TO SALE	
• Vehicle type • Actors involved – who? Hygiene? • Costs • Length of time taken • Temperature (cold chain?) • Hygiene of vehicle • Transport equipment C&D procedures	

STAFF TRAINING	
From whom **Topics** **Frequency**	
MISCELLANEOUS	
Regulatory visits • From whom • Frequency **Monitoring and documentation** **Additional biosecurity measures** • Waste disposal • Visitors **Capacity to recall products** **Challenges** **Pride** **Why people choose them?**	

8. Example of in-depth interview schedule, intermediary trader

General

- How long have you been working selling dairy products?
- Why did you start this job?
- What products do you sell?
- Do you prepare the products or does the person who sells them to you prepare them?
    - *How are they prepared – boiling?*
- How many people/places do you buy milk from?
    - *Do you always get them from the same people/places?*
- How many litres do you get from each client?
    - *Which client is most important?*
- Why do you buy your milk/products from these places/people in particular?
    - *Who chooses who you should buy from?*
    - *What factors help you choose who to buy from?*
    - *Is there anyone you would not buy from?*
- How many litres of each product do you buy per day?
    - *Vary with seasonality?*
- How many days of the week do you work collecting and selling milk?
- Where do you sell your milk/products?
    - *Locations in town (wards; milk point/door-to-door delivery; markets)*
    - *Different days of the week?*
- Who do you sell your milk/products to?
    - *Rural - neighbours/dairy processing unit/other mobile traders/rural market*
    - *Urban – market/milk point/shops/cafes/direct to consumers*
    - *Number of clients in each category*
      Proportions of each (e.g. if you had 100 litres of milk, how many would you sell to….)
    - *Seasonality*
- Why do you sell your milk/products to these places/people in particular?
    - *Who chooses who you should to sell to?*
    - *What factors help you choose who to sell to?*
    - *Is there anyone you would not sell to?*
- Do your customers have regular orders or is it ad-hoc?
    - *Proportions of each*
- How much milk/products do you sell per day?
    - *Litres of milk/mtindi; packets of butter...etc*
    - *What do you do with the leftovers?*
- Does the amount of milk/products you sell vary with season?
- Is there anything you do to the milk/products before sale?
    - *E.g. filtering/boiling. Why/why not?*

Economics

- What price are you currently buying your milk/products for?
    - *Price per litre of milk/packet etc*
- What price are you currently selling your milk/products for?
    - *Price per litre of milk/packet etc*
- What factors affect the price that you will buy the milk/products for?
    - *Is there any seasonality in price? If yes - what is the price in dry season?*
    - *Is the price the same for each client/type of client?*
- What factors affect the price that you will sell the milk/products for?
    - *Is there any seasonality in price? If yes - what is the price in dry season?*
    - *Is the price the same for each customer/type of customer?*
- Who decides on the prices for buying?
- Who decides on the prices for selling?
- Where do you get information on what is a "fair price"?
- How much does the income from milk sales contribute to the overall household income?

Handling, storage and transport practices

- When (what time) do you pick up the milk/products from your clients?
- When (what time) would the cows have been milked/the mtindi made?
- How do you know if you are receiving good quality milk?
    - *What characteristics show it's "good quality"?*
- Are there any things that know of that can help you be sure the milk or other products you receive are good quality?
    - *Eg.organoleptic tests; boiling+clotting; lactometer; ethanol tests*
- Do you do all of those things?
    - *If not – why not?*
- What actions do you take if a client sells/attempts to sell you poor quality milk?
- How do you store the milk/products until you take them for sale?
    - *Refrigeration? – Electricity*
    - *Containers? – Material, provenance, covered or not*
    - *Location – somewhere cool?*
- How long do you store the milk/products until they are sold?
- How far do you have to travel to the points of sale?
    - *Distance, time, means of transport*
- How do you transport the milk/products for sale?
    - *Vehicle, containers, cold chain*
- How long does it take from getting the milk/products to selling to the first customer, and to the last customer?
- How do you keep the equipment you use to store and trade milk/products clean?
    - *Water supply, soap, temperature of water, drying, frequency*
- Why do you think your customers like to buy from you rather than from anyone else?

- Why do you think your clients prefer to sell to you rather than to anyone else?
- Do you do anything with your milk/products to try to maintain or increase its quality before sale?
    - *E.g. boiling. Why/why not?*
- Do you do anything with your milk/products before sale to try to increase your profits?
    - *Is adulteration a common occurrence? At what stage in the chain? When is it most likely to happen? [Circumstances, season]. What materials are added?*

Knowledge and training

- Who do you go to for expertise or advice about how to do this job well?
    - *E.g. friends/training/ traders*
    - *How available is this advice?*
    - *How reliable is this advice?*
- Have you had any training on how to get/sell good quality milk/products?
    - *If yes - From whom? Frequency?*
    - *What topics did it cover?*
    - *Was it useful?*
    - *How about other people who you employ in your business? [if applicable]*

Health perceptions

- Do you think dairy products are good for health?
- Is it ever possible for dairy products to be bad for your health?
    - *If yes - how? (e.g. illnesses it can cause)*
    - *Are there ways that you can help prevent this as a trader?*
    - *If yes – what are they?*
    - *Do you do these things, and if not, why not?*

Self-reported constraints

- What are the main challenges that you encounter in your activities surrounding selling dairy products?

Demographics

- Gender
- Age
- Tribe
- Household size: <18 yy M/F, ≥18 yy M/F

Time use analysis

- Use template sheet for data collection.
- Respondents should be whoever is mainly responsible for collecting/selling milk – note down clearly in log book which role each respondent has. It may be appropriate to take >1 time use diary per household
- Remember to take diaries for both “typical” day and e.g. “market days”

9. Time use record

VCA Unique Identifier____________________[ACT-##(Vil)-###]]
Date________________ Village________________ Ward_______________ VCA type________________

Type of day described (e.g. normal day, market day): ________________________________

Time (SW)	Time (24hh)	Location	Primary activity	Secondary activity	Persons involved	Comments

Appendix 4 – Risk assessment table

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
SMALLHOLDER FARMER								
Milking	**Environmental hygiene**					Medium	Minor	Green
	Infrastructure	Frequent powercuts; cowshed often gloomy despite electric lighting leading to poor visibility	9/12 farmers had electric lighting in the cowshed		Heavy contamination of milk with coliforms even at smallholder farm level (Grimaud, Uganda, 2007; Joseph, Tanzania, 2015; Shija, Tanzania, 2013) (Grimaud, Sserunjogi and Grillet, 2007; Shija, 2013; Joseph, 2015)			
		Tap water is untreated	10/12 farmers exclusively used piped tap water as a water source		Salmonella and E.coli detected in 33% and 90% milk samples from Arusha smallholders respectively (Lubote, Tanzania, 2014), although counts increased along value chain (Lubote, Shahada and Matemu, 2014)			

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
	Holding/ milking area	Hygiene judged inadequate in 6/12 premises owing to poor flooring, drainage, collections of manure, etc. Only 1 farm was judged as having good hygiene, and the remaining 5 as adequate. C&D methods poor on all farms.	7/8 holding areas were spacious, leaving cattle with ample room to move and minimising the risk of teat injuries	Holding area was the same as milking area on all farms	Brucella detected by PCR in 31 % milk sampled from smallholder farmers in a Tanga village (Shija, Tanzania, 2013)(Shija, 2013)			
		7/12 cowsheds had poor ventilation			Limited variation in observed standards of milk hygiene by SH farmers had no significant effect on milk end-product bacterrial counts (Knight-Jones, Zambia, 2016)(Knight-Jones *et al.*, 2016)			
		Wet season can make conditions muddy; dry season dusty			Slightly higher bacterial counts in milk in wet season (Millogo, Burkina Faso, 2009)(Millogo *et al.*, 2010)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Pest control	4/12 reported seeing rodents in cowshed occasionally but took no action to control them	3/9 reported no rodent problem due to cat; 2/9 said never saw rodents					
	Animal health and hygiene							
		On 5/12 farms, animals judged as having poor hygiene	On 4/12 farms, animals had adequate hygiene, and on 3 good					
		3/12 farmers reported delaying calling LFO in response to animal sickness, preferring to try home remedies first	11/12 farmers reported good access to an LFO					
		Large variation in diseases vaccinated against	12/12 farmers had vaccinated against some type of disease, suggesting a positive attitude towards vaccination					
			6/8 farmers reported discarding milk if cow was sick; one reported following direction of LFO					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			Cows were zero grazed in all but one farm		Prevalence of Brucella antibodies lower in zero-grazed versus extensive farms (Arimi et al, Kenya, 2006; Makita, Uganda, 201) (Arimi *et al.*, 2005; Makita, K Fevre *et al.*, 2011)			
		Smallholder farmers may have little by way of formal training, learning their practices from family and peers	Farmers belonging to co-operatives more likely to have received formal training e.g. seminars, study tours		Farmers with no formal training had significantly higher bacterial counts (Joseph, Tanzania, 2015)(Joseph, 2015)			
		Access to expertise (e.g LFOs) was poor/variable in some areas						
	Milking process							
	Milker hygiene	Only 2/11 reported handwashing with soap (neither were observed)	10/11 performed some sort of handwashing prior to milking (e.g. dipping hands in water, pouring water over hands), demonstrating knowledge of need for clean hands prior to milking		Handwashing significantly reduces bacterial load in milk (Sriari, Morocco, 2009)(Srairi *et al.*, 2008)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			Only 1 milker recorded as wearing dirty clothing; 8/11 milked in short sleeves					
	Udder hygiene							
		Some bad hygiene pratices noted when cleaning udder prior to milking, e.g. using dirty cloths; not drying udder off after cleaning, milking into the bucket that was used to clean the udder and thus had contained dirty water	All 12 milkers attempted to clean the udder prior to milking, demonstrating knowledge of need for good teat hygiene. 10/12 used hot water		High prevalence of poor milking hygiene and subclinical mastitis on smallholder farms in Movomero and Njombe districts (Mdegela, Tanzania, 2009) (Mdegela *et al.*, 2009)			
			All milkers lubricated teats before milking, although most used cooking oil rather than purpose-made teat lubricant		Poor udder and teat washing linked to significantly higher bacterial loads (Sriari, Morocco, 2009)(Srairi *et al.*, 2008)			
	Milking procedure	11/12 did not discard foremilk						

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
		7/10 touched dirty areas (e.g. floor, tail) and then the udder during the process of milking, after udder had been cleaned	For 9/12 cases, there were no dust generating activities (such as feeding) recorded around the time of milking					
		No milkers performed organoleptic checks before, during or after milking						
	Milking equipment	Plastic pails used by 9/12 farmers	3/12 used metail pails		Metal pails were acquired through co-op membership (DPU/MCC); these food grade pails are simple to clean and disinfect, unlike plastic buckets. Use of aluminium cans rather than plastic significantly reduces bacterial load in milk (Sriari, Morocco, 2009).(Srairi *et al.*, 2008) Milk sampled direct from cow had zero bacterial count but increased dramatically during milking on farm, reflecting limited hygiene of milking process and equipment (Knight-Jones, Zambia,			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
					2016)(Knight-Jones *et al.*, 2016)			
			6/7 farrmers reported using soap to wash equipment; these same farmers also used hot water					
Handling and storage prior to transport	**Handling and storage**							
		Plastic strainers used for filtering are difficult to clean and may themselves introduce contamination	12/12 farmers filtered milk prior to storage, removing gross contaminants such as dirt and hair			Medium-High	Minor	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Milk tended to be transferred between several (usually plastic) containers, e.g. from pail to larger bucket to measuring cup to storage container; each transferral carried risk of introducing contamination						
		8/12 farmers stored milk in a plastic container (7 buckets; 1 jerry can)	4/12 farmers used a metal bucket or churn to store milk		Metal pails were acquired through co-op membership (DPU/MCC). Use of aluminium cans rather than plastic significantly reduces bacterial load in milk (Sriari, Morocco, 2009)(Srairi *et al.*, 2008)			
			11/12 farmers stored milk in a closed container					
Transport to onward buyer	**Transport to onward buyer**	Journeys to onward purchaser could be long (one DPU reported that some farmers/intermediaries walked up to 1.5 hours to deliver milk to the	9/12 farmers transferred milk immediately to onward purchaser	Length of journey could depend on season, with roads becoming difficult to navigate foot in		High	Minor	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		DPU); for the 2 farmers we interviewed whose milk was collected from their home by a trader, waiting time was up to one or up to three hours, respectively		periods of heavy rainfall				
		No chilling of milk before or during transferral. Ambient temperature could be high during dry season.	All farmers/intermediary traders transported milk in closed containers.		Milk microbial load significantly increased with higher environmental temperatures (Sriari, Morocco, 2009)(Srairi *et al.*, 2008)			
				Individual farmers deliver small quantities of milk to one buyer				
INTERMEDIARY TRADER								
Bulking	**Infrastructure**					Very high		

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Electricity supply was unreliable with frequent power cuts	11/12 traders had electricity at home; for one trader this information was not recorded		Prevalence of Brucella PCT+ milk samples increased from 10% (farmers) to 31% of intermediary traders in Morogoro dairy value chain (Joseph, Tanzania, 2015)(Joseph, 2015)		Moderat e-Major (depends whether trader is small scale or large scale)	Yellow-Red
		1 trader reported using a mix of tap water and stored rainwater	11/12 traders had piped tap water at home; for one trader this information was not recorded					
	Collection procedure							
			Bulk from a smaller number of farmers compared to MCCs/DPUs - most (80%) collected from between 10-20 farmers					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Environmental hygiene	For traders who collect at home: collection area is at homestead rather than in a purpose built area, thus environmental hygiene is often lacking, e.g. collection taking place in muddy/dusty back yard in an area where surfaces cannot be properly kept clean. For traders who collect milk from farmers: environmental hygiene is also poor; vehicles are open to the elements (e.g. pick ups and motorbikes) leaving milk collection vessels and equipment open for exposure to mud splatter and dust						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Quality tests on receipt		9/12 reported at least occasional use of a lactometer to detect adulteration with water.	Report of lactometer use does not necessarily mean that the lactometer is consistently used. Two traders who reported using lactometers at interview did not use the tool when collection was observed. Six traders reported use, but collection was not observed so this could be verified. Only one trader reported lactometer use which was then confirmed on observation.	In a study of milk quality along the dairy value chain in Nakuru and Nyandarua Kenya, Ndungu (2016) found that the lactometer could not always detect prior adulteration of raw milk with water(Ndungu *et al.*, 2016).			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Organoleptic tests were rare; 2/12 reported smelling milk; 1/12 tasted it; and 2/12 visually inspected it		One trader reported that it would be considered rude to smell milk on receipt				
		One trader reported that he was interested in the ethanol test, but that affordable supplies were inaccessible	1/12 reported performing the clot-on-boiling test					
			8/9 would reject milk that they considered poor quality (1/9 would use it to use mtindi); 2 mentioned they would ban repeat offenders					
	Handling	Milk is mixed together, facilitating contamination of large quanitites by even one single farmer's supply	All but one trader filter milk to remove gross contamination (this one trader reported farmers did the filtering)					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Participant observation revealed milk transfer between multiple containers, as well as scooping rather than pouring						
		Participant observation revealed some unhygienic behaviours e.g touching manure whilst doing other activities during the collection process, without then washing hands						
	Equipment	Milk brought by farmers predominantly in plastic buckets or jerry cans; traders collecting milk (e.g. by motorbike) did so predominantly in 50 l jerry cans	One trader collected milk in small jerry cans from each individual farmer and did not mix them until the next morning, to avoid one farmer's milk potentially contaminating the entire supply					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Where traders collected milk at their home, collection vessels were typically kept uncovered througout the period of collection which could be up to an hour						
Heat treatment	**Heat treatment**	Several disincentives against boiling: e.g. decreases the quantity of milk sold; high costs for firewood; need for a modern stove in order to boil large quantities of milk rather than a the traditional stone fire common in both urban and rural settings	11/11 traders reported boiling at least some of the time - e.g. in case of a power outage (where milk/mtindi was stored in the fridge)	Unknown what temperature the milk reaches and for how long each trader keeps boiling, therefore not clear if adequate to ensure pasteurisation.	High temperature short time (HTST - at least 71.7^{o}C for 15s) pasteurization eliminates all vegetative microbes in milk. Some already formed heat-resistant enterotoxins (e.g. of Clostridium botulinum) are not destroyed; neither are spores of C. botulinum and B. cereus; indeed, pasteurization may induce germination of those spores, which are subsequently able to grow and produce toxins in pasteurized milk (Claeys 2013; Holsinger 1997; Hudson 2003) (Holsinger, Rajkowski and Stabel, 1997; Hudson, Wong and	Low-medium (depends on success of pasteuris ation)	Moderat e - Major (depends whether trader is small or large scale)	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
					Lake, 2003; Claeys *et al.*, 2013).			
		Participant observation with one trader revealed she left the milk uncovered to cool for several hours after boiling; flies were observed settling on the milk. A further trader reported also cooling milk in uncovered containers						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Souring	**Souring**	2/6 traders producing mtindi for the rural-to-urban chain produced mtindi from unboiled milk (one exclusively, the other alongside mtindi from boiled milk)	The souring process lowers pH which can inhibit bacterial proliferation and survival	Mtindi was made either through leaving unboiled milk to naturally sour, or by boiling then adding a starter culture (which could be purchased, or could itself be a small quantity of raw milk). We did not collect data on what kind of starter culture each trader used. When comparing two different starter cultures to natural fermentation, Gran (2003) found the highest numbers of E. coli were found in natural fermentation	Experimental studies have shown that souring can inhibit bacterial growth (e.g. Brucella survival is inverse to pH - El Daher 1990(El-Daher, Na'was and Al-Qaderi, 1990); however, other studies have demonstrated various bacteria can survive the souring process under certain conditions e.g. Brucella (Zuniga Estrada(2005 (Zúñiga Estrada *et al.*, 2005)); Listeria (Ashenafi 1994) (Ashenafi, 1994)and Salmonella spp (Ashenafi 1993)(Ashenafi, 1993)	High (if made with raw milk)	Moderat e - Major (depends whether trader is small or large scale)	Yellow

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
				and one of the starter cultures, suggesting type of starter culture can have an effect on the disease risk posed by the product.				

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
					Observational studies have shown that while souring can reduce levels of pathogenic bacteria compared to raw milk (Yigrem, Ethopia, 2015; Yilma, Ethiopia, 2006; Hempen, Gambia/Senegal/Guinea, 2004; Knight-Jones, Zambia, 2016) (Hempen *et al.*, 2004; Yilma and Faye, 2006; Yigrem and Welearegay, 2015; Knight-Jones *et al.*, 2016), levels can still be high and hazardous to human health (Yigrem ibid; Yilma ibid; Hempen ibid). Organisms for which this was the case included: E. coli; Staphylococcus aureus; Bacillus aureus; Clostridia.	Low-medium(if made with boiled milk)	Moderat e - Major (depends whether trader is small or large scale)	Green-Yellow
Storage pre-transport	**Handling and storage**					High	Moderat e - Major (depends whether trader is small or	Yellow
	Equipment	5/12 traders stored milk in plastic buckets and 3/12 in jerry cans. Plastic containers are difficult to clean to an			Tsegaye (2005) found in an experimental study that low levels of E. coli inoculum in fermented milk were followed by			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		adeuqate standard, particularly jerry cans due to their narrow neck preventing access and proper drainage			complete inhibition within 6 hours during storage, suggesting post-fermentation contamination may not be considered as a potential health hazard (although contamination prior to or during fermentation would be). (Tsegaye and Ashenafi, 2005)		large scale)	
		6/12 reported storing milk in uncovered containers in the belief that this prevented spoiling.						
	Location stored	Frequent power cuts can impede adequate refrigeration	6/12 reported storing milk in the fridge					
		6/12 stored milk/mtindi at ambient temperatre, which could be high during some seasons	Suggestions that storing mtindi at ambient temperature may be beneficial? (See Tesgaye 2005)		Experimental results from Tsegaye (2005) suggest that refrigeration of mtindi actually reduced levels of inactivation of E. coli (Tsegaye and Ashenafi, 2005)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Time stored	Mtindi can be kept for 3-4 days before sale; one trader reported up to 7 days (souring processs takes ~24 hours)	Milk not usually stored longer than overnght (owing to risk it might spoil). Suggestion that longer storage times for mtindi could be beneficial?		Experimental results from Tsegaye (2005) suggest that storing mtindi for a longer time (up to 9 days) resulted in inactivation of E. coli O157 (Tsegaye and Ashenafi, 2005)			
Transport to town	**Transport to sale**	No transport vehicles are purpose made for milk/mtindi transport				High	Moderat e-Major	Yellow
	Vehicle	Cold chain is absent; there is no refrigeration of milk/mtindi during transport			Grimaud found that milk transported chilled (4-10^{o}C) had a lower microbial count than unchilled milk in a dairy value chain in Uganda (Grimaud, Sserunjogi and Grillet, 2007)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Containers carried on pick-up trucks and motorbikes are vulnerable to mud splatter/being covered with dust and dirt en route. Dala-dala hygiene can be poor; the vehicles are used for public transport during the rest of the day and as well as human passengers may be used to carry e.g. chickens	Containers carried on dala-dalas are inside the vehicle and protected from the elements					
	Equipment	Milk/mtindi are carried either in plastic buckets (7/12) or jerry cans (4/12) which are difficult to clean	All traders reported cleaning equipment using hot water and soap					
	Duration	Journey time varied from 45 minutes to 1 hour 15 minutes	Access to own transport decreased journey time					
			Journey made in early morning when ambient temperature is cooler					
Wholesale /Retail	**Points of sale**					Very high	Moderate-major	Yellow-Red

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Environment	Hygiene at milk points was generally poor; no permanent stalls/structures so buckets set on dusty/muddy ground and left uncovered, milk points often situated on busy roads; often no shade so buckets in full sunshine for long periods; no basic facilities e.g. water for handwashing (traders might buy tap water from local shops or restaurants for rinsing buckets after use)	Selling direct to shops/other retailers at their location rather than at a milk point where hygiene is poor		Highest prevalence of E.coli (97%) and Salmonella (44%) along Arusha dairy value chain observed in street vendors (Lubote, Tanzania, 2014)(Lubote, Shahada and Matemu, 2014) A study of milk selling points in Dar es Salaam found water source, water shortage and water microbiological quality to be significantly assoicated with higher total bacterial counts in milk (Kivaria, Tanzania, 2006)(Kivaria, Noordhuizen and Kapaga, 2006)			
	Equipment	Plastic buckets, scoops, measuring cyclinders etc that are difficult to adequately sclean			Mean coliform plate count from milk samples from intermediary (bicycle) traders significantly higher than MCCs and kiosks/restaurants (Swai, Tanzania, 2011)(Swai and Schoonman, 2011)			

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
	Handling	Further mixing of milk/mtindi into different containers as sales progress (e.g. as one bucket becomes empty) allows opportunity for contamination			High levels of coliforms found amongst intermediary traders, milk bars and shops/kiosks in dairy value chains in Nairobi/Nakuru (Omore, Kenya, 2001)(Omore *et al.*, 2001)			
		To transfer milk from one container to another (e.g. into purchaser's container), traders tend to scoop milk rather than pour - particularly if trader's container is full and therefore heavy. This can introduce contamination.						
		Some traders allow tasting before buying using e.g. a small plastic cup that is dipped into the product and not washed between customers						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Personal hygiene can be lacking e.g. some traders observed coughing onto their hands then directly serving milk						
	Duration	Sales are prolonged in wet season when there is an excess supply on the market.	Having regular orders means that milk/mtindi can be directly delivered to pre-arranged customers without the need to wait to find buyers in town					
	Knowledge	10/12 traders reported no official training			Training intermediary traders can lead to better milk quality (Omore Kenya, 2011)(Omore *et al.*, 2011)			
DPUs								

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
General - relevant to all value chain activities at DPU	Electricity	Frequent power cuts. One DPU had a generator but this could only provide electricity for one activity at a time (e.g. lighting OR chilling)			A study investigating microbiological quality of raw and pasteurised milk samples sold in Morogoro found that there was no significant difference in coliform levels (Shija, Tanzania, 2015) (Shija, 2013); similar findings were observed in studies from Gambia/Senegal/Guinea (Hempen 2004) and Brazil (Silva 2009)(Hempen *et al.*, 2004). Such results could indicate inadequate pasteurisation and/or post-pasteurisation contamination			
	Water	Tap water was directly piped from mountain and was not treated before use. One DPU supplemented tap water with water from a nearby stream.	Both DPUs had piped tap water		Insufficient or poor quality water for cleaning milk handling equipment can result in milk residues on equipment surfaces which provide ideal nutrients for bacterial growth (van Kessel 2004)(Van Kessel *et al.*, 2004)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Environmental hygiene		Environmental hygiene was good in both DPUs (e.g good drainage, unpolluted surroundings, etc)					
	Building	Only one DPU was purpose-built, and even this was not done so in cosultation with experts so had an unsuitable layout	Structural integrity was good in both buildings					
		Almost no biosecurity in place at either DPU	One DPU obliged us to wear washable plastic flip flops during our visit					
		Only one DPU had a one-way system for products, but staff did not enact a one way system and frequently walked from dirty to clean areas						
		One DPU had very few handwashing facilities and no soap, one had sinks in every room but no soap.						
		WCs at neither DPU had handwashing facilities or soap	WC was removed from milk handling areas in both DPUs					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			Good lighting in both DPUs when electricity functioned					
		Poor ventilation at both DPUs; premises were damp and smoky (both due to heat treatment method)						
	Surfaces, strucutres and fittings	Cracked floors in both DPUs	White tiled walls in both DPUs; easy to clean					
		In one DPU the surfaces were grubby desite being food-grade and easy to clean	Food grade surfaces e.g. metal tables					
		One DPU stored containers and equipment on rough wooden shelves, dusty and difficult to clean	Spacious premises with good access to and around equipment in both DPUs, facilitating cleaning					
	Pests	One DPU had flies buzzing around the premises during participant observation	Both DPUs had window screens to prevent entry of birds/insects (although screens were compromised in places)					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			Both DPUs reproted rodents were rare					
	Handling	Risky practices at both DPUs observed e.g. dipping cups into milk, scooping to transfer milk	Both DPUs used hot water and soap to clean equipment					
			Most staff wore PPE at both DPUs, eg white coats and oots					
		One staff member reported that she was obliged to come to work even when ill as she was the only staff member who knew how to make a specifc product	Staff at both DPUs reported washing hands before commencing each processing activity; note that handwashing facilities were sparse and that handwashing was not observed, so this may not be the case. However, it does denote at least an awareness of the need for good hygiene.					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Knowledge	A staff member at one DPU reported that training was very infrequent and often unsuitable	Both DPUs reported various sources of trraining e.g. free seminars from Land O' Lakes; study tours to agricultural colleges/other DPUs					
	Regulation	Lack of faith in TBS as shown by lack of belief at one DPU that products were sub-standard as according to TBS written report (high level of coliforms)	At least one visit per year from both TFDA and TBS (2/2), at which time products are tested and buildings and procedures inspected					
		Confusing and non-context specific regulatory/policy environment	TFDA/TBS have regulatory powers to ban poorly functioning premises and have exerted these powers in the study area					
			One DPU once had occasion to recall a product and succcesfully managed to get a proportion of the product they had sold on off the selves. TBS supported this action (it was a					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			voluntary initiative of the DPU, not precipitated by a regulatory authority).					
Bulking	**Collection procedure**							
	Reception area	Bulk from a large number of farmers (70-200)	Both DPUs collected milk in a designated area on a covered porch with a smooth cement floor			Medium	Minor	Green
		DPU that collected into a tank left this tank open througout the hour long collection period	Fast speed of reception at both DPUs, although one DPU reported that farmers could queue up to 30 minutes waiting for the DPU to open					
	Quality tests		Both did lactometer test on all deliveries. One DPU did the ethanol test if they had suspcions milk was spoiled/adulterated; the other did the		In a study of milk quality along the dairy value chain in Nakuru and Nyandarua Kenya, Ndungu (2016) found that the lactometer could not always detect prior adulteration of raw			

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
			ethnaol test as a supplementary test of random farmers on random days of the week. One DPU also smelled milk delivered by motorbike intermediaries.		milk with water(Ndungu *et al.*, 2016)			
			Both DPUs sanctioned bad quality milk with milk rejection, warnings and possible bans					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Heat treatment	**Heat treatment**	Heat treatment was low-tech; milk churns were lowered into a cauldron of boiling water. It could take 30 minutes to 1 hour to achieve the required temperature. Potential for inadequate heating of the milk (eg. cold spots, not heating through) and subsequent failure to pasteurise	Milk was boiled for several minutes at 90-95^{o}C, a higher temperature and time range than required for HTST pasteurisation. Temperature was ascertained by using a temperature gauge (1/2) or thermometer (1/2)		High temperature short time (HTST - at least 71.7^{o}C for 15s) pasteurization eliminates all vegetative microbes in milk. Some already formed heat-resistant enterotoxins (e.g. of Clostridium botulinum) are not destroyed; neither are spores of C. botulinum and B. cereus; indeed, pasteurization may induce germination of those spores, which are subsequently able to grow and produce toxins in pasteurized milk (Claeys 2013; Holsinger 1997; Hudson 2003) (Holsinger, Rajkowski and Stabel, 1997; Hudson, Wong and Lake, 2003; Claeys *et al.*, 2013). Small-scale pasteurisation has been shown to be ineffective in the field, with high residual bacterial counts following thermal treatment (Belli,	Low-medium (depends on effective ness of pasteuris ation)	Severe	Green-Yellow

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
					Cameroon, 2012).(Belli *et al.*, 2013)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Cooling is slow (takes around 1 hour to cool to 29°C, before then being transferred to a chiller room or tank to be futher chilled)	Churns are left sealed during cooling, preventing entry of contaminants		Milk churns were transferred to a cold water bath for cooling. Once cooled they were transferred to a cold room (1/2), the contents transferred to a chiller tank; or used for further processing. Slow cooling post-pasteurisation was identified as a risk for increased microbial growth at a small-scale dairy processing unit in Kenya (Ndungu, Kenya, 2016) (Ndungu *et al.*, 2016)			

	Souring	Equipment used to stir milk and culture mix is not sterile	Milk boiled before adding culture	Souring process observed at one DPU only. Process: Add culture to milk can, stir with a long metal implement (this implement was partially sterilised by dipping in boiling water prior to use, but it was not fully submerged); using a plastic cup, scoop and transfer milk from churn to buckets, then pour into a jerry can and leave 2 days to sour	Experimental studies have shown that souring can inhibit bacterial growth (e.g. Brucella survival is inverse to pH - El Daher 1990; however, other studies have demonstrated various bacteria can survive the souring process under certain conditions e.g. Brucella (Zuniga Estrada(2005); Listeria (Ashenafi 1994) and Salmonella spp (Ashenafi 1993) (El-Daher, Na'was and Al-Qaderi, 1990; Ashenafi, 1993, 1994; Zúñiga Estrada *et al.*, 2005). Observational studies have shown that while souring can reduce levels of pathogenic bacteria compared to raw milk (Yigrem, Ethopia, 2015; Yilma, Ethiopia, 2006; Hempen, Gambia/Senegal/Guinea, 2004; Knight-Jones, Zambia, 2016) (Hempen *et al.*, 2004; Yilma and Faye, 2006; Yigrem and Welearegay, 2015), levels can still be high and hazardous to human	Low-medium	Major	Green-Yellow

					health (Yigrem ibid; Yilma ibid; Hempen ibid). Organisms for which this was the case included: E. coli; Staphylococcus aureus; Bacillus aureus; Clostridia.				

Souring		Handling and containers could introduce contaminants (e.g. scooping versus pouring; use of plastic buckets)			Tsegaye (2005) demonstrated that if milk is already contaminated prior to addition of culture, fermentation may not control E. coli O157 growth (Tsegaye and Ashenafi, 2005)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Packaging	**Packaging**	Packing is small-scale and done by hand, not machine	Both DPUs bought in purpose-made food packaging materials		Aseptic packaging poses great risk for post-pasteurisation contamination. Pasteurised milk is an almost sterile substratum so is ideal for new colonisation by microbes (Grimaud, Uganda, 2007) (Grimaud, Sserunjogi and Grillet, 2007)	Medium	Moderate (milk is not packaged; most mtindi is sold unpackaged)	Green
		1/2 DPUs did not use any PPE whilst packaging. (1/2 reported wearing gloves for packaging activities, but we did not observe any)						
Storage pre-transport	**Storage**	Door to cold room left ajar during our visit; temperature increased to 10^{o}C	One DPU stored all products in a cold room (aimed to be 4-6^{o}C). The other stored boiled milk in a chilling tank at 4^{o}C, and mtindi at ambient temperature.	Milk was stored overnight only; mtindi for 1-3 days		Low-medium	Severe	Green-Yellow
		Some milk and mtindi to be sold in bulk was	Some milk was stored in food grade milk churns					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		stored in plastic buckets.						
Transport to town	**Transport to sale**							
	Environment	Pick-up trucks used for delivery were open to the elements and difficult to clean. Rural roads were not paved and thus route into town is dusty and/or muddy, contaminating buckets, churns and distribution equipment	Transport began in early hours of the morning when temperature is cool. One DPU had an enclosed chiller vehicle which they used for longer journeys.		Grimaud found that milk transported chilled (4-10°C) had a lower microbial count than unchilled milk in a dairy value chain in Uganda (Grimaud, Sserunjogi and Grillet, 2007)	Low-Medium	Severe	Green-Yellow
	Equipment	Some milk and bulk mtindi were transported in large plastic buckets, difficult to clean	Some milk was transported in food grade metal churns. All containers were closed during transport.		In a study of milk quality at milk selling points in Dar es Salaam, Kivaria found that using plastic containers was associated with significantly higher total bacterial counts than metal containers (Kivaria 2006) (Kivaria, Noordhuizen and Kapaga, 2006)			
	Duration	Journey times were >1hour with no cold chain.						
Wholesaleing/	**Points of sale**							

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Environment	Sales were made from the back of a pick-up; vehicle was dirty, sales environments could be muddy and wet in wet season and hot and dusty in dry season. Buckets were not shaded from sun, and could be left open for long periods during sales				High	Severe	Red
	Equipment	Quantities were measured out using plastic equipment which is difficult to clean and could get further contaminated on the trasnport/sales route						
	Handling	Risky practices observed during participant observation, e.g. scooping rather than pouring milk to transfer to different vessels; no use of gloves/PPE when handling milk; no						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		access to handwashing on sales route etc						
	Duration	Time to last sale could be several hours, with products unrefrigerated and exposed to the sun	Having regular orders means that milk/mtindi can be directly delivered to pre-arranged customers without the need to wait to find buyers in town					
MCCs								
General - relevant to all value chain activities at MCC	Electricity	Electricity supply is variable with frequent power cuts	All MCCs had access to electricity, and 3/6 had generators in case of power cuts		Proportion of Brucella antibody +ve samples from MCCs was significantly higher than from intermediary traders (Schoonman, Tanzania, 2011)(Schoonman and Swai, 2011)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Water	1/5 only had access to tap water from a house up the street. Staff thus had to carry water from the house to the MCC, limiting the amount of water available for C&D	All had access to piped tap water; 4/5 had a tap either in or directly outside the building		Insufficient or poor quality water for cleaning milk handling equipment can result in milk residues on equipment surfaces which provide ideal nutrients for bacterial growth (van Kessel 2004)(Van Kessel *et al.*, 2004)			
	Environmental hygiene		Environmental hygiene was good in all 5 MCCs (e.g good drainage, unpolluted surroundings, etc)					
	Building	No biosecurity measures in place at any of the MCCs	4/4 were purpose-built to be MCCs rather than using requisitioned buildings. Strucutral integrirty was good in all 5 premises.					
		No MCC had a one-way system						
		No MCC had handwashing facilities or soap available						
		No latrine had handwashing facilities	Latrines were at a distance from the premises in 5/5 MCCs					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Surfaces, structures and fittings	Wooden tables/shelves used for storing equipment/collecting milk at all premises; difficult C&D	Food grade tanks used to collect milk at 4/5 premises	Food grade equipment has NGO origin (Land O' Lakes)				
		Cracked flooring in 2/5 premises would make C&D difficult	Equipment spaced well with good access for cleaning in all premises					
	Rodents	Lack of screens on windows in 4/5 premises allows entry of insects and potentially small birds	4/5 reported rodents had never been a problem; 1 reported rats in harvest season which they dealt with using traps					
	Knowledge	No premises had a plan in place to continue training after Land O' Lakes programme finished	5/5 reported getting free training seminars from Land O' Lakes; 1 mentioned a previous study tour to Tengeru agricultural college and 1 mentioned possibility of organising paid training from TAMPA					
		5/5 reported that new staff receive no prior induction training and just learn on the job						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Regulation	No inspections by any food safety authority e.g. TFDA, TBS	1/5 reported that Land O' Lakes had observed their procedures and made recommendations					
Bulking	**Collection procedure**							
	Reception area	MCCs bulk from a large number of farmers (lowest 45, highest 200)	5/5 collected milk in a designated area on a covered porch with a smooth cement floor		Microbiological analysis along dairy value chain in Tanga region found that the proportion of Brucella milk ring test +ve samples from MCCs was significantly higher than intermediary (bicycle) traders (Schooman, Tanzania, 2011)(Schoonman and Swai, 2011); Swai, Tanzania, 2011)(Swai and Schoonman, 2011). A similar study in Ethiopia found that Staphylococcus aureus contamination rates were significantly higher at MCCs (72%) compared to farms (43.5%) (Makita Ethiopia, 2011)(Makita *et al.*, 2012)	High	Severe	Red

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
			Speed of reception was immediate or fast in 5/5 premises					
		1/5 did no quality tests at all, although reported using a lactometer 1-2 times per week	4/5 used a lactometer for all farmers, and 1/5 also used the ethanol test at random		In a study of milk quality along the dairy value chain in Nakuru and Nyandarua Kenya, Ndungu (2016) found that the lactometer could not always detect prior adulteration of raw milk with water (Ndungu *et al.*, 2016)			
		Plastic equipment was used by all 5 premises as vessels to collect/measure/ transfer milk; difficult to esure adequate C&D	3/5 collected milk into food-grade metal containers (churns and/or tank)					
			All 5 premises filtered milk on collection (through gauze or sieve) to remove gross contamination					
			All 5 premises rejected milk that was found to be poor quality, and imposed sanctions on					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
			offenders (e.g bans, fines)					
	Handling	Risky practices observed at all premises e.g. dipping thumbs in milk, squeezing the gauze to force milk through, scooping milk rather than pouring to transfer between vessels						
			4/5 premises used some form of PPE e.g. white overcoats, wellington boots, headscarves					
		C&D procedures inadequate- in two observed premises, buckets were washed inside and out using the same cloth, i.e. after mud had been washed off the outside of one bucket using a cloth, this same cloth was used to wash the inside of the next bucket. At one	All premises washed equipment with hot water and soap after each collection/distributio n					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		premises C&D was carried out next to the outdoor tap in the dark with only the light from a mobile phone						
Storage pre-transport	Storage		2/5 sold milk immediately ie is not stored; 3/5 stored it in a chiller tank between 2-4°C			Low	Severe	Green
Transport to town	**Transport to sale**							
	Environment	Pick-up trucks used for delivery were open to the elements and difficult to clean. Rural roads were not paved and thus route into town is dusty and/or muddy, contaminating buckets, churns and distribution equipment	Transport began in early hours of the morning when temperature is cool. One DPU had an enclosed chiller vehicle which they used for longer journeys.		Grimaud found that milk transported chilled (4-10°C) had a lower microbial count than unchilled milk in a dairy value chain in Uganda (Grimaud, Sserunjogi and Grillet, 2007)	Low-Medium	Severe	Green-Yellow

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Equipment	Some milk and bulk mtindi were transported in large plastic buckets, difficult to clean	Some milk was transported in food grade metal churns. All containers were closed during transport.		In a study of milk quality at milk selling points in Dar es Salaam, Kivaria found that using plastic containers was associated with significantly higher total bacterial counts than metal containers (Kivaria 2006) (Kivaria, Noordhuizen and Kapaga, 2006)			
	Duration	Journey times were >1hour with no cold chain.						
Wholesaleing/retailing	**Points of sale**							
	Environment	Sales were made from the back of a pick-up; vehicle was dirty, sales environments could be muddy and wet in wet season and hot and dusty in dry season. Buckets were not shaded from sun, and could be left open for long periods during sales				High	Severe	Red

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Equipment	Quantities were measured out using plastic equipment which was difficult to clean and can get further contaminated on the transport/sales route						
	Handling	Risky practices observed during participant observation, e.g. scooping rather than pouring milk to transfer to different vessels; no use of gloves/PPE when handling milk; no access to handwashing on sales route etc						
	Duration	Time to last sale could be several hours, with products unrefrigerated and exposed to the sun	Having regular orders means that milk/mtindi can be directly delivered to pre-arranged customers without the need to wait to find buyers in town					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Wholesale/Retail	Infrastructure	Market has only one tap so water supply is scarce. Traders have to buy water (filling their containers at the market tap), further limiting the amount of water available to them for their activities			A study of milk selling points in Dar es Salaam found water source, water shortage and water microbiological quality to be significantly associated with higher total bacterial counts in milk (Kivaria, Tanzania, 2006) (Kivaria, Noordhuizen and Kapaga, 2006)	Very high	Major	Red
	Environmental hygiene	Traders sell their produce from buckets spread out on the ground, which is dusty in dry season and can become very muddy in wet season thus contaminating traders' buckets and equipment	A few traders sit under tarpaulins, small trees and one under a large umbrella, offering some shade to some - but not all - of their buckets					
		Most traders do not have any shade for their buckets; in dry season the temperatures can become very hot and the buckets are in full sunshine						
		There are many flies at the market						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		The dairy section is located next to a hot snack tent; this tent blows smoke over the dairy traders						
	Collection/delivery procedure	Deliveries can occur well into the heat of the day		Mtindi is delivered in plastic buckets on handcarts, dala dalas and pick-ups. Market traders either buy 20 litre buckets directly, and/or bring their own containers and buy specific quantities				
		Participant observation revealed that ther is a lot of dipping and scooping in order to transfer mtinidi from suppliers' containers to market traders' containers - could introduce contamination						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Quality tests on receipt	Tasting vessel generally not washed after use and later used by customers, possibly contaminating mtindi	4/7 market traders reported doing organoleptic tests to check quality before purchase (eg tasting, smelling, looking/stirring to inspect texture)		Tsegaye reports that fermented milk contaminated with E.coli O157 does not give off any odour, therefore it is difficult to depend on sensory evaluation of the product as a sign of safety (Tsegaye, Ethiopia, 2006)(Tsegaye and Ashenafi, 2005)			
	Equipment	Majority of traders sold mtindi from plastic buckets and used other plastic equipment such as measuring cups and funnels for decanting quantities into customers' containers, and small cups or lids to allow potential customers to taste before purchase. Plastic materials are difficult to clean and disinfect	Buckets were sealable; most traders covered any mtindi that was not being sold		In a study of milk quality at milk selling points in Dar es Salaam, Kivaria found that using plastic containers was associated with significantly higher total bacterial counts than metal containers (Kivaria 2006) (Kivaria, Noordhuizen and Kapaga, 2006)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Bulky buckets often stored near the market place at friend/other contact's home or workplace to save having to carry them home; negates the opportunity for thorough C&D	Traders took care to ensure no equipment was rested directly on the ground e.g. measuring cups were left inside buckets; funnels were rested on top of closed buckets					
	Handling	Various unhygienic practices observed e.g dipping in fingers to check taste or texture scooping, mixing different buckets, using the same vessel for tasting for all customers, eating at the stall						
		No market traders wear any PPE and there are no handwashing facilities available to traders						

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
		Customers may be encouraged to scoop up a taster sample of mtindi themselves, such that it is handled by scores of people by the end of the day	Strong customer preference for mtindi that had not been through many intermediaries; one market trader who was herself a livestock keeper and was selling her own mtindi always sold out fast					
		Lack of water or a fire to heat it means that C&D procedures are substandard; for example we observd one trade buy half a bucket of cold tap water to clean all of her buckets. Towards the end of the cleaning proces, this water is very dirty. Unlike intermediary traders, many market traders do not take their empty buckets home for further cleaning - rather they store them nearby in readiness for the next market day.	Some (a minority of?) traders used soap when cleaning their equipment					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		During this time, any milk residues will provide an ideal environment for bacterial replication.						
		On participant observation, some mtindi on sale was visibly dirty						
		Time till last sale can be very long; some traders reported selling up until 7pm, approximately 12 hours after the market open, with mtindi sitting at ambient temperature all this time	In hot weather there is usually a shortage of mtindi, so it sells out quickly (eg by 11am) with less time sitting out in the sunshine					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Knowledge	No market traders reported receving any formal trading						
	Regulation	Regulation/inspection is reactive and haphazard, only instigated as a response to an outbreak						
SHOPS - MILK								
General - applies to all activities in this stage of the value chain	**Infrastructure**							
	Electricity	Frequent power cuts interfere with refrigeration	At least some access to electricity in most Moshi Municipality wards meant that most residents could access shops with refrigerators		High levels of coliforms found amongst intermediary traders, milk bars and shops/kiosks in dairy value chains in Nairobi/Nakuru (Omore, Kenya, 2001)(Omore *et al.*, 2001)			
	Water		All shops we visited had access to nearby tap water, either their own tap or a municipal tap a short walk away		A study of milk selling points in Dar es Salaam found water source, water shortage and water microbiological quality to be significantly associated with higher total bacterial counts in milk (Kivaria, Tanzania, 2006)(Kivaria,			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
					Noordhuizen and Kapaga, 2006)			
	Knowledge	No shopkeepers had any formal training on milk hygiene						
	Regulation	Ward/health officers not specifically interested in safety of dairy products being sold	Frequent inspections by ward/health officers					
Heat treatment	Heat treatment	Thermos has narrow neck and may not be easy to clean	Boiled milk stored in thermos flask to retain heat	Unknown what temperature the milk reaches and for how long each vendor keeps boiling, therefore not clear if adequate to ensure pasteurisation.		Low-medium (depends on success of pasteuris ation)	Moderat e	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Retail	Delivery procedure	Buying from urban intermediary traders rather than direct from rural sellers/urban livestock keepers introduces extra steps in the value chain	Trader setlling directly to the shop rather than via a milk point, where there are opportunities for contamination	Shopkeepers might be unaware where their suppliers had come from, ie were they urban or rural intermediary traders		Very high (if not boiled)	Major	Red
	Quality tests on receipt	No shop reproted using a lactometer to check milk purchased was not adulterated	One shopkeeper reported performing the clot on boiling test to detect spoilage			Medium (if boiled)	Major	Yellow
			Organoleptic tests - 3/5 said they visually inspected the product. For mtindi only, 2/5 tasted it (explaining they could not taste milk to check quality as it was raw)			Low (if from urban livestock keeper)	Moderat e (if from urban livestock keeper, as lower quanitite s involved)	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Handling and storage	All shopworkers stored milk/mtindi in either plastic buckets or jerry cans, bar one who stored (boiled) milk in a thermos. These containers are difficult to clean, particularly jerry cans which have a narrow neck	Containers were sealed to prevent contamination					
		Frequent powercuts reported breaking up refrigeration; also milk may not be rerigerated at all times e.g. one shopworker with a fridge had the milk out on the counter for the entire length of our visit (>30 minutes) because she was "expecting customers" (no customers bought milk during our visit)	4/5 stored milk in a fridge; 1 had no fridge but boiled milk and stored in a thermos					
		Usually at least 2 people working in a shop, increasing the number of people handling the product						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Same plastic vessels used to serve hot milk to all customers. Thermos would lose heat and cool down, creating ideal environment for bacterial growth						
			C&D with hot water and soap reported by 3 of 4 shopworkers, and cold water and soap by 1. Containers and equipment were washed after each use.					
MAMA LISHE - MILK								
Heat treatment	Heat treatment	Thermos has narrow neck and may not be easy to clean; may introduce contaminants when boiled milk is transferred	Boiled milk stored in thermos flask to retain heat	Unknown what temperature the milk reaches and for how long each vendor keeps boiling, therefore not clear if adequate to ensure pasteurisation.		Low-medium (depends on success of pasteurisation)	Moderate	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Retail	Retail	Selling point is roadside; lots of dust/mud/exhaust facilitating contamination. Often no shade from sunshine.		Tend to have fewer customers than restaurants/caf es		Medium	Minor	Green
		When heat begins to be lost from the thermos, the warm environment provides ideal environment for bacterial growth	Milk stored in sealed thermos					
		Same few plastic containers used to serve everybody						
Restaurants, cafes, institutions - milk								
Heat treatment	Heat treatment	Thermos has narrow neck and may not be easy to clean; may introduce contaminants when boiled milk is transferred	Boiled milk stored in thermos flask to retain heat	Unknown what temperature the milk reaches and for how long each vendor keeps boiling, therefore not clear if adequate to ensure pasteurisation.		Low-medium (depends on success of pasteuris ation)	Moderat e	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Retail	Retail		Fixed premises reduces risk of contamination	Large numbers of customers each day		Medium	Moderate	Green
		When heat begins to be lost from the thermos, the warm environment provides ideal environment for bacterial growth	Milk stored in sealed thermos					
SHOPS - MTINDI								
General - applies to all activities in this stage of the value chain	Electricity	Frequent power cuts interfere with refrigeration	At least some access to electricity in most Moshi Municipality wards meant that most residents could access shops with refrigerators		High levels of coliforms found amongst intermediary traders, milk bars and shops/kiosks in dairy value chains in Nairobi/Nakuru (Omore, Kenya, 2001) (Omore *et al.*, 2001)			
	Water		All shops we visited had access to nearby tap water, either their own tap or a municipal tap a short walk away		A study of milk selling points in Dar es Salaam found water source, water shortage and water microbiological quality to be significantly associated with higher total bacterial counts in milk (Kivaria, Tanzania, 2006)(Kivaria, Noordhuizen and Kapaga, 2006)			

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Knoweldge	No shopkeepers had any formal training on milk hygiene						
	Regulation	Ward/health officers not specifically interested in safety of dairy products being sold	Frequent inspections by ward/health officers					
Souring	**Souring**	5/9 traders sold mtindi through the urban-to-urban value chain. Leftover milk was likely to be highly contaminated owing to high levels of handling and long periods at ambient temperature.	Having regular, pre-arranged orders with customers to decrease possibility of leftovers	Amount of leftovers depended on factors such as season (higher supply of milk in wet season); religious calendar (lower demand for milk during periods of fasting such as Ramadan); school calendar (lower demand for milk during school closure)		Very high	Major	Red

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		As leftover milk would already be beginning to sour, it would not be not possible to boil it at this point as it would clot and then not make mtindi. Therefore only the souring process could decrease pathogen load, not boiling.						
Retail	**Retail**							
	Delivery procedure	Buying from urban intermediary traders rather than direct from rural sellers/urban livestock keepers introduces extra steps in the value chain	Trader settling directly to the shop rather than via a milk point, where there are opportunities for contamination	Shopkeepers might be unaware where their suppliers had come from, ie were they urban or rural intermediary traders		Medium	Major (Moderate if selling from ULK as quantities are lower)	Yellow (Green if from ULK)
	Quality tests on receipt	Quality tests available for milk (eg lactometer, clot on boiling) cannot be used for mtindi	2/5 tasted mtindi as a quality check					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		All shopworkers stored mtindi in either plastic buckets or jerry cans. These containers are difficult to clean, particularly jerry cans which have a narrow neck						
	Handling and storage	Mtindi often stored at ambient temperature	May be refrigerated					
			Containers were sealed to prevent contamination					
		Frequent powercuts reported breaking up refrigeration	C&D with hot water and soap reported by 3 of 4 shopworkers, and cold water and soap by 1. Containers and equipment were washed after each use.					
		Mtindi potentially stored for several days before sale	Difficult to adulterate mtindi without consumer noticing - disincentive to adulteration					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Usually at least 2 people working in a shop, increasing the number of people handling the product						
MAMA LISHE - MTINDI								
Retail		Selling point is roadside; lots of dust/mud/exhaust facilitating contamination. Often no shade from sunshine.	Mtindi stored in covered containers	Tend to sell only to a small number of customers		High	Minor	Green
		Same few plastic containers used to serve everybody	Tend to buy small amounts for purchase that day					
		Mtindi stored in plastic containers that are difficult to clean						
RESTAURANTS, CAFES, INSTITUTIONS - MTINDI								
Retail	Retail	Mtindi stored in plastic containers that are difficult to clean	Fixed premises reduces risk of contamination		Large numbers of customers each day	High	Moderat e	Yellow
		May be stored several days at ambient temperature	Mtindi may be stored in a refrigerator					
URBAN LIVESTOCK KEEPERS								
Milki ng	**Environmental hygiene**							

Risk pathway step	**Area of consideration (Codex GHP)**	**Factors that increase risk**	**Factors that decrease risk**	**Further comments and context**	**Relevant literature**	**Est'd probab-ility**	**Est'd conse-quence**	**Est'd risk**
	Infrastructure	Frequent powercuts	4/4 ULKs had electric lighting in the cowshed			Medium	Minor	Green
		Unclear of source of tap water and if water is treated	3/4 ULKs had own tap water					
	Holding/milking area	Densely packed living quarters meant that other livestock kept closeby, leading to chickens/goats/flies entering 4/4 cowsheds	Hygiene judged good in 3/4 premises; in all 4 premises there was ample space in cowshed, leaving cattle with ample room to move and minimising the risk of teat injuries	Holding area was the same as milking area on all farms				
	Pest control	2/4 report high numbers of rodents in harvest season	2/4 reported taking action to poison rodents when observed					
	Knowledge	High turnover of cowboys makes sustainable training difficult	Access to expert knowledge usually good e.g. LFOs, radio programmes					
	Animal health and hygiene	On 3/4 premises, animals judged to have poor hygiene						
		Reported access to LFO is variable						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Variation in diseases vaccinated against	4/4 farmers had vaccinated against some type of disease, suggesting a positive attitude towards vaccination					
			2/4 ULKs reported discarding milk if cow is sick; one reports boiling and giving to dogs; remainer reports following LFO's advice					
	Milking process							
	Milker hygiene	Only 1/4 reported using soap for handwashing	All performed some sort of handwashing using hot water prior to milking					
	Udder hygiene		All 4 used hot water to clean udders					
			All milkers lubricated teats before milking, half using cooking oil and half using purpose-made teat lubricant					
	Milking procedure	No milker discarded foremilk						

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		2/2 observed touched dirty areas and the the udder (after washing hands)	No dust-generating activities recorded around milking for 3/3 premises					
		None of 3 premises performed organoleptic checks before, during or after milking						
	Milking equipment	Plastic pails used by 3/4 milkers	1/4 used metal pail					
			3/3 reported cleaning milking equipment with hot water and soap					
Handling and storage	**Handling and storage**					Medium-High	Minor	Green
		Plastic strainers used by 2/2 milkers observed; these are difficult to clean and may themselves introduce contamination	4/4 milkers filtered milk prior to storage, removing gross contaminants such as dirt and hair					

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Milk tended to be transferred between several (usually plastic) containers, e.g. from pail to larger bucket to measuring cup to storage container; each transferral carried risk of introducing contamination						
		3/4 ULKs stored milk in a plastic container (2 buckets; 1 jerry can). 1/4 used metal pail, but this had previously contained dirtied water from cleaning the udder	3/4 ULKs stored milk in closed container					
Heat treatment				None of the ULKs we interviewed/observed boiled milk before sale, but assume that as at other steps, the majority of pathogens will be eliminated provided that heat is applied		Low-medium	Minor	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
				at a sufficient temperature for sufficient time to enable HTST pasteurisation				
Souring				None of the ULKs we interviewed/observed made mtindi, but assume that souring will reduce the number of viable bacteria, and that levels of contamination are generally low compared to for intermediary traders as there is no bulking step		Low-medium	Minor	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
Transport to onward buyer				None of the ULKs we observed sold milk wholesale to shops, but assume that the same containers would be used as for retail at homestead and that distances travelled would be small		Low	Minor	Green
Wholesale				None of the ULKs we observed sold milk wholesale to shops, but assume that farmers would sell only to one local shop so exchange of containers would be minimal		Low	Minor	Green
Retail		No chilling of milk/mtindi before or during transferral to onward buyer	Waiting time for customers to purchase milk was maximum 30 minutes			Medium	Minor	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		Scooping milk/mtindi to measure out quantities can introduce pathogens	Customers bring own containers for onward transferral; ULK does not have responsibility of providing clean vessels					
CONSUMER - MILK								
Consumption - milk	Transport to homestead	May be transported in vessels that are difficult to clean	Distances are very short			Low	Moderate-Major	Green
	Storage	Usually stored in plastic containers at ambient temperature or in the refrigerator	Milk is consumed on day of purchase; storage times are short			Low	Moderate-Major	Green
	Preparation for consumption	A minority do not boil milk before consumption	Most consumers boil before consumption			Low-medium	Moderate-Major	Green-yellow
			Milk from urban livestock keepers not bulked milk, less likely to be contaminated owing to shorter value chain, and is more recently produced compared to milk from rural areas so will have a lower bacterial load at end of storage			Low (ULK)	Moderate-Major	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
		The population groups who consume large amounts are at higher risk of illness (e.g. children, postnatal mothers, sick, elderly)						
CONSUMER - MTINDI								
Consumption -mtindi	Transport to homestead	May be transported in vessels that are difficult to clean	Distances are very short			Low	Moderat e	Green
	Storage	Usually stored in plastic containers at ambient temperature or in the refrigerator. Can be stored for several days	May be bought for consumption on day of purchase			High	Moderat e	Yellow
			Mtindi made by urban livestock keepers not made from bulked milk, less likely to be contaminated post-souring, will also have been produced more recently compared to mtindi from rural areas			Medium (ULKs)	Moderat e	Green

Risk pathway step	Area of consideration (Codex GHP)	Factors that increase risk	Factors that decrease risk	Further comments and context	Relevant literature	Est'd probab-ility	Est'd conse-quence	Est'd risk
	Preparation for consumption	Eaten as bought - no preparation possible	Mtindi made by urban livestock keepers likely to have lower level of bacteria owing to aforementioned reasons			High/Medium (ULKs)	Moderate	Yellow/ Green (ULKs)
		The population groups who consume large amounts may be at higher risk of illness (elderly, sick)						

References for risk assessment:

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