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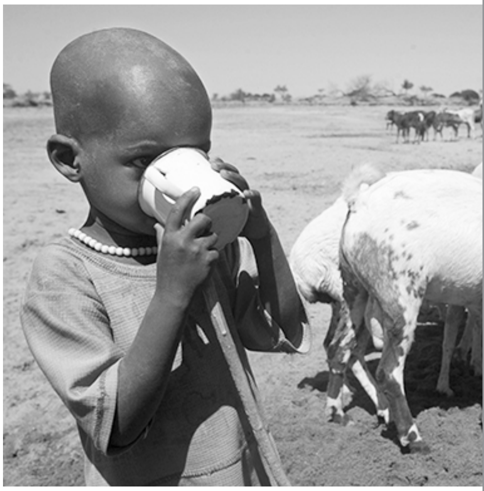

working paper

IMPACT OF MASTITIS IN SMALL SCALE DAIRY PRODUCTION SYSTEMS

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IMPACT OF MASTITIS IN SMALL SCALE DAIRY PRODUCTION SYSTEMS

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Contents

Abbreviations used in the text

WTO	World Trade Organization
CM	Clinical Mastitis
CMT	California Mastitis Test
HF	Holstein Friesian breed
WSD	White Side Test
SCC	Somatic cell count
BMSCC	Bulk milk somatic cell count
SCM	Sub-clinical Mastitis
HFC	Holstein×Friesian cross
SFMT	Surf Field Mastitis Test
SSA	Sub-Saharan Africa

Executive summary

Mastitis is the most prevalent production disease in dairy herds worldwide and it is well documented as disease with a heavy burden in developed countries, while very limited information is available for developing countries. This paper reviews the existing literature on the topic of mastitis to assist in the analysis of its occurrence in developing countries, focusing on small-scale farming systems and to provide information on the economic dimension of the disease in resource-poor environments. To the author's knowledge, there are no pertinent published studies and so the purpose here is to summarize most of the data available on mastitis in resource-poor environments, with a focus on small-scale producers.

The papers reviewed show a significant prevalence of the disease throughout numerous herds in different countries in Africa and Asia, especially in its sub-clinical form. Economic estimates were limited to a few countries and conducted with disparate methodologies.

Another issue highlighted is the lack of awareness among farmers of the sub-clinical form of the disease, and this aspect is of fundamental importance because of the possibility of spreading infectious agents through the herd. The lack of medical treatment means, as demonstrated, an increase in the occurrence of mastitis cases on the farm, a consistent decrease in milk yield (up to 33% per quarter infected), a public health risk due to consumption of unsafe milk, and less efficient processing of milk.

The data collected and organized can be used as a starting point to concentrate future efforts on the study and control of mastitis and its impact in developing countries, with a focus on its relevance for vulnerable small-scale farmer households.

Introduction

Mastitis is a multi-etiological and complex disease, which is defined as inflammation of parenchyma of mammary glands. It is characterized by physical, chemical and, usually, bacteriological changes in milk, and pathological changes in glandular tissues (Radostis et al., 2000). The occurrence of disease is an outcome of interplay between three major factors: infectious agents, host resistance, and environmental factors (Gera and Guha, 2011).

Mastitis is a global problem as it adversely affects animal health, quality of milk and the economics of milk production, affecting every country, including developed ones and causes huge financial losses (Sharma, Maiti and Sharma, 2007). There is agreement among authors that mastitis is the most widespread infectious disease in dairy cattle, and, from an economic aspect, the most damaging (Tiwari *et al.,* 2010; Sharma *et al.,* 2012; Elango *et al.,* 2010; Halasa *et al.,* 2007; Mostert *et al.,* 2004).

Clinical and sub-clinical mastitis are the two major forms of the disease:

- Clinical mastitis results in alterations of milk composition and appearance, decreased milk production, and the presence of the cardinals signs of inflammation (pain, swelling and redness, with or without heat in infected mammary quarters). It is readily apparent and easily detected.
- In contrast, detection of mammary quarters with sub-clinical mastitis is more difficult because signs are not readily apparent (Kivaria, 2006) and, because of the lack of any overt manifestation, its diagnosis is a challenge in dairy animal management and in veterinary practice.

The sub-clinical form is 15 to 40 times more prevalent than the clinical form, and usually precedes the clinical form and is of long duration (Seegers, Fourichon and Beaudeau, 2003). It is important to emphasise that the sub-clinically affected animals remain a continuing source of infection for herd mates (Islam *et al.,* 2011). There are different levels for detection of mastitis: an individual cow level in the herd, and a more large-scale testing for bulk milk (Kivaria, 2006). Regarding the individual cow level, the sub-clinical form of the disease can be detected by bacteriological examination and somatic cell counts (SCC) (Muhammad *et al.,* 2010).

SCC has been accepted as the best index to use to predict udder infection in cows, and has been used extensively as an indicator since the 1960s (Pyorala, 2003; Kivaria, 2006). Under field conditions, determination of SCC in milk is usually done using the California Mastitis Test (CMT); in fact, CMT scores are directly related to average SCC (Radostis *et al.,* 2000; Pyorala, 2003). CMT has the advantage of being very inexpensive and is a test with real-time results for selection of the quarters for subsequent bacteriological examination (Kivaria, 2006). At the same time, when the number of infected cows in a herd is high, bulk milk somatic cell count (BMSCC) may be elevated.

Mastitis is a complex disease, and thus there is no simple solution for its control, so understanding its occurrence, the related risk factors, and the mastitogenic pathogens involved, are fundamental elements in developing a control programme.

Mastitis: a worldwide production disease of dairy cows

As briefly introduced above, mastitis is a heavy burden for the dairy sector worldwide: it is a costly disease due to direct losses (a reduction of output due to mastitis) and expenditure (additional inputs to reduce the level of mastitis), both with negative implications for milk hygiene and quality (Hogeveen, Huijps and Lam, 2011; Coulon *et al.,* 2002).

In developed countries, many studies have been conducted. The annual losses per cow from mastitis in the United States of America in 1976 were estimated to be US$ 117.35 per cow per year (Blosser, 1979); two decades later these losses had increased to US$ 185 to $ 200 per cow per year (Costello, 2004). In 1976, annual losses from mastitis in USA were estimated at a total of US$ 1294 billion, and had increased to US$ 2 billion by 2009 (Viguier, 2009).

Its negative impact can be a huge constraint on the development of profitable dairy enterprises, and this is particularly relevant in the developing world, in which the dairy industry has a strong role in the livelihood of poor people (von Braun, 2010).

The small-scale dairy sector contributes significantly to alleviating poverty and reducing malnutrition, particularly in rural and peri-urban areas, in addition to providing regular income for the household and employment opportunities for women and animal attendants (Karimuribo *et al.,* 2006).

Livestock kept or produced in small-scale farming systems are an important component of the agricultural economy in the developing world (McDermott, Randolph and Staal, 1999) and small-scale dairy development is a powerful tool for actively involving the poor in boosting rural economic growth, initiating a process of change and improving livelihoods (FAO, 2009). In Kenya alone, dairying is a very significant source of income and food for an estimated 625 000 small-scale producer households (Muriuki, Mwangi and Thorpe, 2001). In India, marginal producers and small-scale farmers own over 60% of all milch animals and constitute the core milk production sector (Kurup, 2001).

Hence, as a first step, it is of fundamental importance to investigate the occurrence of this disease, in both clinical and sub-clinical forms, and especially in small-scale farmer herds. Many studies have been conducted in developing countries to assess the real prevalence of clinical and sub-clinical mastitis in dairy herds, in the various farming systems.

A first step in mastitis control programmes is to quantify udder health by determining the prevalence and incidence of both clinical and sub-clinical mastitis, and assess bacteriological aspects of the disease (Karimuribo *et al*., 2000).

Even if a good number of studies on the occurrence of the disease are available, the information is in most cases relevant to only small geographical areas, and cannot be generalized.

In fact, mastitis has not really been studied systematically in the developing world, resulting in only limited information being available on the prevalence of disease and associated economic losses.

Small-scale systems

Livestock systems in developing countries are highly varied, ranging from extensive pastoral systems to large-scale commercially oriented industrial production systems.

A schematic classification has been given in SOFA 2009 (FAO, 2009), where the production systems are categorized as:

- Grazing systems (extensive and intensive);
- Mixed farming systems (rainfed and irrigated); or
- Industrial systems.

Small-scale farming has been defined in terms of numbers of animals per producer. Small-scale farming systems usually have several animal species within the farm, and these different types of animals may have different purposes in the system: provision of food for the family; cash from product sales (e.g. milk, beef, eggs); capital assets ('walking banks'); provision of manure for crops and pastures; fibre for clothes; traction for ploughing; and transport (Herrero *et al.*, 2007). In tropical Africa, livestock production is mostly practised in small-scale farming systems, and in Asia over 80% of the milk is produced by small-scale farmers (Herrero *et al.*, 2007; Moran, 2009). For example, the small-scale farmer dairy system in the Dar es Salaam region of Tanzania supplies about 86% of the raw milk consumed by the city dwellers (Kivaria and Noordhuizen, 2007). There are often arguments as to what constitutes small-scale dairying. Some authors consider small-scale to be from 2 to 15 animals (Devendra, 2001), others consider it to be up to 20 milking animals plus replacement heifers (Moran, 2009), or even up to 50 cattle (Phiri, Benshop and French, 2010). Swai and Karimuribo (2011) reported that small-scale dairy units in Tanzania generally have three to four animals, one or two of which are lactating cows. The milk produced is used both for home consumption and for sale, either directly by farmers or to middlemen, who transport the milk to urban areas or processing units. Most of the small-scale systems are of a subsistence nature and the resource-poor situations have not enabled intensification and specialization, mainly because of access to services and resources. The main difference between small-scale production systems in sub-Saharan Africa and Asia is the higher prevalence of pasture-based systems in most part of Africa, while in Asia the majority are crop-animal systems (Devendra, 2001). Improved animal health care is an essential issue for small-scale farm development. In small-scale units, diseases often rank, with the availability of feed resources and nutrition, as the most important constraints on production (Devendra, 2001).

Occurrence of clinical and sub-clinical mastitis in developing countries

MASTITIS IN ASIA

From an Asian perspective, the prevalence of mastitis is increasing in parallel with the development of new, high-milk-producing breeds of cows and buffaloes. Other factors have been identified (Sharma *et al.,* 2012) that contribute to increased spread of the disease, including: lack of awareness; delay in disease detection in the absence of visible signs of abnormal milk; unhygienic milking practices; and delayed and incomplete treatment of clinical and chronic mastitis (Sharma *et al.,* 2012). See Figure 1.

Studies conducted in different part of India highlight the high level of occurrence of bovine and bubaline mastitis all over the country (Table 1). In India, milk production takes place in millions of small and very small units, in terms of both land and animals, that are scattered throughout the country (Kurup, 2001). Hence, it is relevant to estimate what is the real occurrence of mastitis in the small-scale producer sector in different parts of India.

Table 2 collates some reported data from studies in Bangladesh, Pakistan and Thailand, which focused on the occurrence of mastitis. It is evident that the sub-clinical form is extensively spread throughout the herds. Dairying is considered a strong tool to develop a village micro-economy in Bangladesh in order to alleviate rural poverty and improve rural livelihoods (Shamsuddin *et al.,* 2007), and small-scale dairy farms are the main producers of milk in Bangladesh (World Bank, 2008). In a study conducted by Uddin and co-workers (2012), with the aim of identifying the major constraints on the small scale dairy farmer sector, it emerged that "disease" is the most frequent problem identified (Uddin *et al.,* 2012) by the small-scale farmers. Similarly, mastitis has been identified as one of the limiting factors in the development of a dairy industry in Pakistan (Bilal *et al.,* 2004), and a major impediment to increasing milk production in Thailand (Boonyayatra and Chaisri, 2005).

MASTITIS IN SUB-SAHARAN AFRICA

Studies conducted in different parts of sub-Saharan Africa (SSA) reveal that mastitis, SCM and CM are widespread in the small-scale dairy cow sector. In fact, in numerous studies prevalence exceeds 50%, and it is clearly a threat for small-scale producers (See Table 3). In East and West Africa, most milk is produced by small-scale dairy units, so it is evident that the disease not only has a negative impact at farm level, but also more globally in the dairy sector in general.

An effort has been made by different authors to assess the occurrence of mastitis among dairy herds in Ethiopia, where this disease is considered a major constraint, and identified as a primary cause of poor milk production in the country (Girma *et al.,* 2012). Similarly, in a range of East African countries attention has been given to this disease, studying the prevalence, the risks and also the awareness of farmers. All the studies analysed and reported here demonstrate a high prevalence (16–80%) of sub-clinical mastitis, implying that it could be among the major constraints limiting optimum productivity in small-scale dairy cattle operations.

Figure 1. Prevalence of mastitis in different Asian Countries, based on data from various studies and production systems (Source: Sharma *et al.*, 2012)

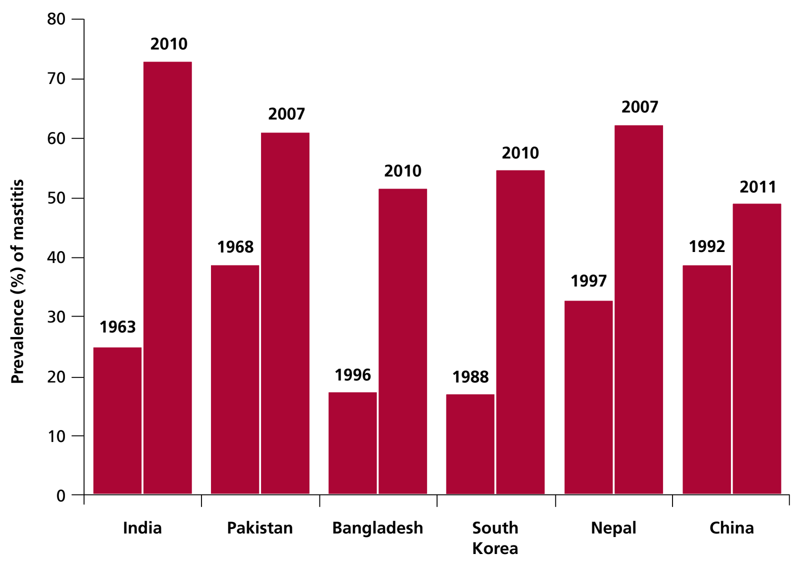


Table 1. Reported incidence and prevalence of mastitis in India

Species	Prevalence/ Incidence	Methodology	Sample Size	Remarks	References
Buffalo	I – 18.74% CM; 32.9% SCM	Milk cultures	2057 animals in State of Haryana	Rural and urban environment	Sharma and Sindhu, 2007.
Cow	I – 30.61% SCM	pH, SCC, milk cultures, antibiotic sensitivity test	98 Jersey cross	Cows from various mini-dairy units	Elango *et al.*, 2010.
Cow	I – 33.75% SCM		80 Holstein-Friesian cross (HFC)	Cows from various mini-dairy units	Elango *et al.*, 2010.
Cow	I – 49.75% A – 23.10% Q SCM	SCC	400 animals	Crossbreds, Gir and Malvi. Urban and rural environment; organized and un-organized dairies	Tiwari *et al.*, 2000.
Buffalo	I – 13.6% A SCM 3.1% Q CM	pH, SCM, CMT	125 animals	Animals presented at the Teaching Veterinary Clinical Complex	Lakshmi Kavitha *et al.*, 2009.
Cow	I – 46% SCM	SCC, milk cultures	250 HFC	Peri-urban dairy farms	Joshi and Gokale, 2006.
Cow	I – 6.4% CM average			Review of many authors (1962–1989)	Singh and Singh, 1994.
Buffalo	I – 3.84% CM average			Review of many authors (1962–1989)	Singh and Singh, 1994.

Notes: A = on per-animal basis; Q = on per-quarter basis; CM = Clinical Mastitis; SCM = Sub-clinical Mastitis; HFC = Holstein-Friesian cross; I = incidence; CMT = California Mastitis Test; SCC = somatic cell count.

Table 2. Reported incidence and prevalence of mastitis in Bangladesh, Thailand and Pakistan

Species	Incidence/ Prevalence	Methodology	Sample size	Remarks and source
		Bangladesh		
Cow (crossbred)	P – 27.5% SCM	CMT, WST, SFMT	200 milk samples	BAUDF and rural areas of Tangail Sadar. Islam *et al.*, 2011.
Cow	P – 51.3% SCM	Milk cultures	158 cows randomly selected	30 from SGDF + 128 from farms in Sylhet region. Rahman *et al.*, 2010.
Cow	P – 8% CM	Visual inspection, CMT		Only cows with udder problems examined. Small-scale farm units. Shamsuddin *et al.*, 2010.
		Thailand		
Cow	16–59%, SCM	Milk cultures	4 units with av. 6.4–9.5 milking cows.	Small-scale farm units. Boonyayatra and Chaisri, 2005.
Cow	63.8% SCM (185/285 tested CMT >3)	CMT and milk cultures	258 cows from 16 small-scale farming units.	Small-scale farm units. Jarassaeng *et al.*, 2012.
		Pakistan		
Buffalo	P – 4% Q, CM; 27% Q, SCM	Milk cultures, SFMT	50 animals	Data from 3 institutional herds. Khan and Muhammad, 2005.
Cow	P – 5.5% Q, CM; 36% Q, SCM	Milk cultures, SFMT	50 crossbred cows	Khan and Muhammad, 2005.
Buffalo	P – 77.87% (1) SCM	SFMT	300 buffaloes	From 4 different areas. Bachaya *et al.*, 2005.
Cow	P – 18.21% CM; 33.67% SCM	SFMT	291 cows	From 300 livestock farmers. Hameed *et al.*, 2012.
Buffalo	P – 24.6% CM	SFMT	382 buffaloes	From 300 farms. Hameed *et al.*, 2012.
Buffalo	P – 44% SCM	WST, milk cultures	600 buffaloes	From organized, small-holdings and individual holding private dairy buffalo farms in four districts of Punjab Ali *et al.*, 2011.

Notes: BAUDF = Bangladesh Agricultural University Dairy Farm; Q = on per-quarter basis; CM = Clinical Mastitis; CMT = California Mastitis Test; SCM = Sub-clinical Mastitis; SFMT = Surf Field Mastitis Test; SGDF = Sylhet Government Dairy Farm; WST = White Side Test. (1) Average number of animals infected.

Table 3. Incidence and prevalence of mastitis in dairy cows in sub-Saharan Africa

Incidence/ Prevalence	Methodology	Sample size	Remarks and source
		Ethiopia	
I – 21.26% CM	SCC	90 cows	Small-scale dairy farms (1–5 cows) Almaw, Molla and Melaku, 2012.
I – 14.9% CM; 25.4% SCM	CMT, milk cultures	307 cows (indigenous, Jersey and HF)	Animals under various managements. Dego and Tareke, 2003.
P – 4.9% CM; 30.6% SCM	Clinical examination, indicator paper test	183 cows (HF, crossbreds and local zebu)	Small-scale dairy farms (av. 5.5 cows) Moges *et al.*, 2012.
P – 8.6% CM; 28.6% SCM	CMT	245 cows (HF, crossbreds and local zebu)	Small-scale dairy farms Abera *et al.*, 2012.
P – 23.18% SCM	CMT, milk cultures	384 zebu	Small-scale dairy farms Girma *et al.*, 2012.
P – 16.1% CM; 36.67% SCM	CMT, milk cultures	180 cows (local and crossbreds)	Referred to Alemanga Woreda Vet. Clinic Sori, Zerinhum and Abdicho, 2005.
P – 24.6% Q; 68% A SCM	CMT, milk cultures		Small-scale dairy farms Mekonnen and Tesafaye, 2010.
P – 26.5 A CM; 38.1% A SCM	CMT, milk cultures	223 cows (indigenous and cross-bred)	Small-scale dairy farms Lakew, Tolosa and Tigre, 2009.
P – 65% A SCM	CMT	83 cows	Small-scale dairy farms (1–9 cows) Mungube *et al.*, 2005.
		Tanzania	
P – 80% SCM	CMT	188 cows	Small-scale dairy farms. SCM = CMT >1 Karimuribo *et al.*, 2000.
P – 51.6% A SCM	CMT, milk cultures	91 cows from 69 farms	Small-scale dairy farms (av. animals 1.6 ±0.6) Mdegela *et al.*, 2009.
P – 90.3% A SCM	CMT	182 cows from 62 herds	Small-scale dairy farms Kivaria, Noordhuizen and Kapaga, 2004.
P – 76% A; 46% Q SCM	CMT	Cows from 400 herds	Small-scale dairy farms Karimuribo *et al.*, 2006.
		Kenya	
P – 19.6% CM	Milk cultures	250 cows from 87 herds	Small-scale dairy farms Shitandi *et al.*, 2004.
		Madagascar	
P – 9% CM; 79% SCM	CMT	133 animals from 33 dairy farms	Small-scale dairy farms Ravaomanana *et al.*, 2004.
		Zimbabwe	
P – 4.8% CM; 16.3% SCM; 49.3% FM	SCC, milk cultures	584 cows from 73 farms	Small-scale dairy farms Katsande *et al.*, 2013.

Notes: A = on a per-Animal basis; CM = Clinical Mastitis; CMT = California Mastitis Test; FM = incidence at farm level (at least 1 positive animal in the herd); HF = Holstein×Friesian cross; I = incidence; P = prevalence; Q = on a per-Quarter basis; SCC = somatic cell count. SCM = Sub-clinical Mastitis.

Risk Factors: Hosts, Management Practices, Environment

Mastitis is a difficult problem to comprehend because, as noted earlier, it is a disease caused by many factors, both in large and in small-scale herds. Micro-organisms are responsible for the infection, but for them to enter the mammary gland and establish themselves to the point that they cause an infection, a multitude of factors may be involved. There are many factors acting simultaneously, and the disease generally involves interplay between management practice and infectious agents, but with other factors, such as genetics, udder shape or climate. (Awale *et al.,* 2012; Sori, Zerinhum and Abdicho, 2005).

Being aware that especially sub-clinical mastitis is highly spread through herds in developing countries, it is important to identify risk factors and to assess their contribution to the occurrence of the disease.

Identification of area-specific and/or farm-specific risk factors is important for the design of control programmes for mastitis in cows (Almaw, Molla and Melaku, 2012). The main factors identified as a risk for the occurrence of the disease are considered below. The information comes from various authors and many studies in different geographical areas.

Occurrence of mastitis is generally higher in high yielding bovines. Holstein Friesian (HF), Jersey or HF and Jersey crossbred dairy cows are generally more susceptible to mastitis than indigenous breeds (Moges *et al.,* 2012; Sudhan and Sharma, 2010; Joshi and Gokale, 2006; Dego and Tareke, 2003; Sori, Zerinhum and Abdicho, 2005; Lakew, Tolosa and Tigre, 2009), although Rahman and co-workers found no significant difference between HF crossbreds and zebu (Rahman *et al.,* 2009).

Cows with the most pendulous quarters appear to be the most susceptible to mammary infections, the pendulous udder exposes the teat and udder to injury and pathogens easily adhere to the teat and gain access to the gland tissue (Almaw, 2004; Sori, Zerinhum and Abdicho, 2005). Similarly, long teats increase the risk of accidental trauma and such lesions constitute potential sources of micro-organisms, which increases the probability of quarter infection (Almaw, 2004). The prevalence of mastitis was noticed to be higher in cows with lesions and/or tick infestation on the skin of the teat and/or udder than in cows without this factor (Dego and Tareke, 2003; Moges *et al.,* 2012; Lakew, Tolosa and Tigre, 2009. Mulei (1999), in Kiambu district, Kenya, also recorded a prevalence of 71% of SCM in quarters with teat lesions.

The prevalence of SCM increases with age, increasing lactation number and parities (Dego and Tareke, 2003; Joshi and Gokale, 2006; Rahman *et al.,* 2009; Awale *et al.,* 2012; Hameed *et al.,* 2012; Mungube *et al.,* 2004; Girma *et al.,* 2012; Moges *et al.,* 2012; Lakew, Tolosa and Tigre, 2009; Jarassaeng *et al.,* 2012; Islam *et al.,* 2011). It has been shown that the higher prevalence of mastitis in older animals is due to increased potency of teats and increased degree and frequency of previous exposure in multiparous old cows (Girma *et al.,* 2012).

Islam and co-workers in 2011 recorded the highest prevalence of the disease in the early stage of lactation, both in crossbreds and local breeds, in Bangladesh (Islam *et al.,* 2011); the same was reported by Dego and Tareke in Southern Ethiopia

(2003), and by Lescourret and Coulon (1994), in whose study the impact of mastitis appeared to be more marked in early lactation, both because mastitis cases inducing important or very important milk losses were more frequent, and because their impact was felt over a longer period.

Seasonality in the incidence of mastitis has been studied. The occurrence of mastitis varies from season to season, because growth and multiplication of organisms depends on specific temperature and humidity. Incorrect ventilation, with high temperature and relative humidity, encourages the multiplication of various bacteria. Exposure of animals to high temperature can increase the stress of the animal and alter immune functions (Sudhan and Sharma, 2010). Joshi and Gokale reported that, in India, animals were more prone to SCM in the monsoon season compared with summer or winter (Joshi and Gokale, 2006). This matches the findings of Patil and co-workers (2005) related to buffaloes in Karnataka State, India. Similarly, in Ethiopia, it was noticed by Dego and Tareke (2003) that the prevalence was higher in the rainy season than in the dry season.

Different types of milking methods (e.g. stripping, knuckling, full hand method, machine milking) are practised by dairy farmers. Faulty milking practices, especially knuckling, cause great harm to tissue and they become prone to infection (Sudhan and Sharma, 2010). A stripping type of hand-milking technique was the predominant method used (90%) in the study conducted by Kivaria and co-workers in Tanzania, and they assumed that this technique causes microscopic trauma of the teat epithelium (Kivaria, Noordhuizen and Kapaga, 2004.). In Pakistan, Hameed *et al.,* (2012) recorded the highest prevalence of mastitis in animals with calf suckling, probably because of the injury inflicted while dragging away during suckle. In addition, Prabharkar and co-workers (1990) isolated mastitis-causing bacteria from the pharynx of suckling calves. Further, Hameed *et al.,* (2012) identified a higher prevalence of the disease in animals milked by folded thumb compared with animals milked by a full hand method. Also, fast milking is a negative factor that contributes to the development of the disease (Awal *et al.,* 2012). Moreover, it has been noticed in numerous studies that the vacuum pressure in the pipe-line of mechanical milking systems has a great impact on sub-clinical mastitis (Jarassaeng *et al.,* 2012; Rasmussen and Madsen, 2000). Higher or lower vacuum pressure directly involve teat tissue and the teat canal, leading to decreasing natural protection of the udder, and becoming pre-disposing factors for teat duct colonization by environmental pathogens (Zecconi *et al.,* 1992)

Moisture, mud and manure present in the environment of the animals are primary sources of exposure for environmental mastitis pathogens. Milking hygiene reduces the pathogenic organisms and prevents them from inhabiting the immediate environment or skin of the animals and minimizing their spread during milking process (Sudhan and Sharma, 2010). In fact in many studies in Ethiopia (such as those conducted by Lakew, Tolosa and Tigre, 2009; Dego and Tareke, 2003; Mungube *et al.,* 2004), a higher prevalence is recorded in cows with poor hygiene in the milking process. Similarly, in India, the practice of regular teat dipping is not common at small-dairy unit level (Sudhan and Sharma, 2010).

Intensively managed cows present a higher risk for the development of mastitis, followed by semi-intensive, with least risk among extensively managed animals (Sori, Zerinhum and Abdicho, 2005). In all housing systems, high stocking density, dirty bedding or ground, infected utensils, poor ventilation and high humidity are important risk factors. Housing increases the risk of mastitis because of the confinement of the animals, and the multiplication of pathogens in the litters elevate teat challenge, and consequently mastitis. Mastitis prevalence increases in herds housed under poor stable and drainage conditions, and in herds where mastitic cows were not milked last. This is much more evident for coliform mastitis (Sudhan and Sharma, 2010). The findings agree with the findings of Hameed and co-workers (2012) in Pakistan, who observed higher prevalence of mastitis in backyard housed animals than in animals kept on the street and open areas, possibly due to the highly contaminated environments in backyard areas.

Major causative agents: contagious and environmental pathogens

Mastitis is caused by several species of common bacteria, fungi, mycoplasmas and algae (Batavani, Asri and Naebzadeh, 2007). Most mastitis is of bacterial origin, with just a few of species of bacteria accounting for most cases. Mastitis pathogens are categorized as contagious or environmental (Kivaria, 2006). Contagious pathogens live and multiply on and in the cow's mammary gland and are spread from cow to cow, primarily during milking.

Contagious pathogens include: *Staphylococcus aureus, Streptococcus agalactiae*, *Mycoplasma* spp. and *Corynebacterium bovis* (Radostis *et al.,* 2000).

Environmental mastitis can be defined broadly as those intra-mammary infections (IMI) caused by pathogens whose primary reservoir is the environment in which the cow lives (Smith, Todhunter and Schoenberger, 1985). The most frequently isolated environmental pathogens are Streptococci, other than *S. agalactiae*, commonly referred to as environmental streptococci (usually *S. uberis* and *S. disgalactiae*) and gram-negative bacteria such as *Escherichia coli*, *Klebsiella* spp. and *Enterobacter* spp. (Hogan *et al.,* 1999).

Mycotic infections are another important cause of mastitis. In an unpublished study, mentioned in a paper from Kivaria and Noordhuizen (2007), it was established that 90% of small-scale dairy farmers in Tanzania were unaware of the causal factors of mastitis and so did not know how to prevent the disease. Many available studies in developing countries had the aim of conducting microbiological investigations to understand each pathogens role in causing mastitis in different areas.

Data analyses limited to a few hundred samples from small areas or regions can not be extrapolated to national level because there could be substantial geographical variation in the distribution of mastitis-causing bacteria (Riekerink *et al.,* 2008).

This is especially true when we speak about countries with a range of agro-climatic conditions with varying husbandry practices, such as India (Hegde *et al.,* 2013).

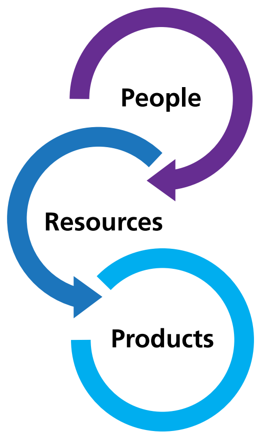
Because mastitis is a complex disease involving various factors, identifying the main pathogens and risk factors, at herd level, is fundamental to developing proper preventive and control measures.

It is important to remember that contagious mastitis prevalence is considerably influenced by the milking procedures followed by milkers. Thus correct milking procedures such as milking mastitic cows last, and proper sanitation of utensils, milker's hands and udder before milking could help to improve the situation. The frequency of isolation of coliforms (*E. coli*, *Enterococcus faecalis*, etc.) and other micro-organisms causing environmental mastitis is usually directly influenced by unhygienic housing conditions (Mekonnen and Tesafaye, 2010).

Many studies from Asian countries have reported that *S. aureus* is the chief aetiological agent of mastitis in cattle and buffaloes (Sharma, Maiti and Sharma, 2007; Rahman *et al.,* 2010; Khan and Muhammad, 2005; Ali *et al.,* 2011).

Similarly in many countries in Africa, Staphylococci were the most frequent isolated agents in small-scale dairy herds. In Tanzania, many studies recorded *Staphylococcus* spp. as the predominant mastitis-causing pathogens isolated on small-scale farms (Kivaria and Noordhuizen, 2007 out of 1964 samples, and Mdegela *et al.,* 2009 out of 47 cows). In Uganda, Byarugaba *et al.* (2008) found the same

Figure 2. People resources and products



information out of 688 quarter milk samples; the same was recorded in Kenya by Shitandi *et al.*, 2004 (sample of 989 quarters), and in Ethiopia by Mekonnen and Tesafaye (2010).

THE ECONOMIC DIMENSION OF MASTITIS

Starting from the basic conceptual model developed by McInerney (1987), the economic analysis includes three major components: people, resources and products.

- It is people who want things and make decisions, providing the driving force for economic activity.
- Resources are the physical factors and services that are the basis for generating the products, and, as such, are the starting point of economic activity.
- Products are goods and services that are regarded as the outcome of economic activity.

Animal disease in this context can be considered an influence affecting the transformation process of resources into products, and causes extra resource use or reduces production. The effects may or may not be immediately visible. To express the physical effects in economic terms, the 'value' of products and 'cost' of resources are required. The idea of value is not intrinsic in any product or service, but is determined by people's request for the products, and is relative to its availability (supply and demand) (McInerney, 1987).

There have been many articles published worldwide on the economics of mastitis. Firstly, it is important to clarify the terminology of different terms commonly used when conducting economic analysis of animal diseases. Petrovski, Trajcev and Buneski (2006) made an effort to define these terms and in this paper the following terms will be used as defined:

- Loss (L) implies a benefit that is taken away (e.g. the production loss experienced because contaminated milk must be discarded) or it represents a potential benefit that is not realized (decrease in the milk yield).

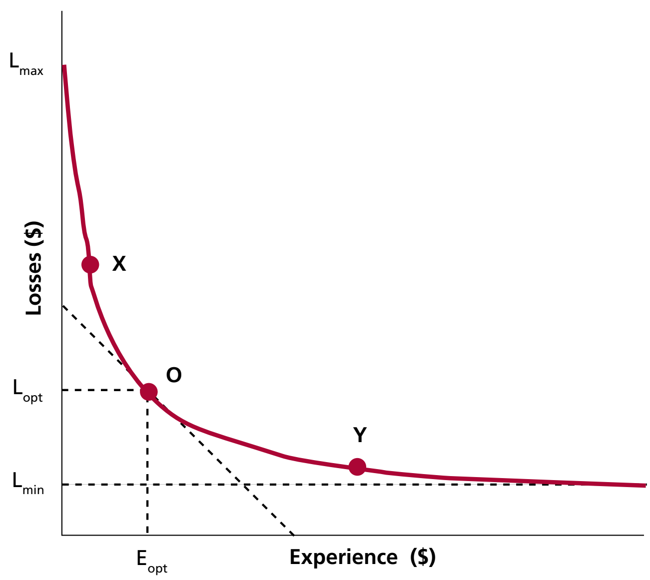
- Expenditures (E) represent some economic effects of disease that are manifested as extra inputs into livestock production (such as treatment and prevention of mastitis).
- Economic cost (C) is the monetary value of all the economic effects, both losses and expenditures, consequent upon the occurrence of the disease.

However there will be an inverse relationship between production losses and control expenditures as demonstrated by the schematic representation in Figure 4 proposed by Hogeveen, Huijps and Lam (2011).

The graph proposed by Hogeveen, Huijps and Lam (2011) is a schematic representation of the relationship between losses due to mastitis and expenditure for control of mastitis. It shows that if no control measures are taken, the losses are a

Figure 3. Costs are the sum of losses and expenditures

Figure 4. Conceptual approach of cost effectiveness assessment



Source: Hogeveen, Huijps and Lam, 2011 maximum (L_{max}); in contrast, with maximum control expenditure, the losses due to mastitis will be at a minimum (L_{min}). At point X the losses are high, and at point Y the expenditures is not outweighed by reduced losses. The Point O is where the avoidable costs are zero and the total expenditure is optimal (E_{opt}).

Economic analysis is not a form of financial accounting as the main concern in economics is to rank alternative disease control measures. As suggested by Morris (1999), because mastitis is a disease that occurs in most livestock herds in a country and zone, and causes some economic impact each year, it requires a partial budgeting approach at herd level, and a simple cost-benefit analysis at national level. Further, Petrovski, Trajcev and Buneski (2006) suggested a framework that employs the following parameters to estimate the economic costs associated with mastitis:

- an estimate of the incidence and prevalence of mastitis in the population as a pre-requisite for the estimation of its real costs for the dairy sector;
- severity of the physical effects of mastitis on milk production, which will depend on many factors, including virulence of the mastitis causal agents, genetics, stage of lactation, age of the cow, and udder defence mechanisms;
- identification of the prevention and treatment measures undertaken;
- valuation of the production losses, which are likely to be influenced by the age, breed, milk yield before mastitis occurred, milk price, premiums and penalties, mastitis-causing organisms, inflammation grade and distribution; and
- other factors, such as culling, replacement and farm management.

Although the costs of factors differ between regions and countries, the economic principles behind them remain the same (Awale *et al.*, 2012).

FACTORS INFLUENCING MASTITIS COST AT FARM LEVEL (QUANTIFICATION METHODS)

The economic damage from mastitis, either clinical or sub-clinical, can be condensed to a few categories, as listed in Figure 5. The arrow is a graphic schematization of the logic path that leads to the assessment of the economic impact.

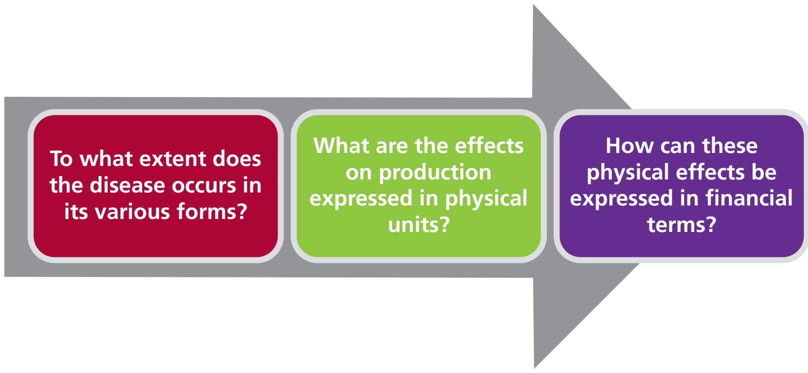
Milk yield losses

Intra mammary infection, even if restricted to sub-clinical levels, has been reported to affect milk production negatively. The reduction in milk production is largely due to physical damage to the mammary parenchyma of the affected mammary gland (Zhao and Lacasse, 2008).

Histological analyses have been widely used in the past and are still used today for assessing damage to secretory tissue in the bovine mammary gland caused by mastitis pathogens. Benites *et al.* (2002) examined the mammary parenchyma of dairy cows from which micro-organism were isolated, and recorded that 96.9% of samples showed an inflammatory response (oedema, mammary epithelial cell damage, and polymorphonuclear neutrophil infiltration), tissue repair process, or both. At the same time, in mammary glands without evidence of micro-organisms, there were no histological changes. These results clearly indicate that the presence of micro-organisms is associated with tissue damage.

At the same time, it must be remembered that the occurrence of an inflammation can cause decreased appetite and lowered food intake due to pain and decreased movement, which will have a negative impact on milk production.

Figure 5. Logical path to assess economic impact



Many techniques have been used to estimate production losses from mastitis in dairy cattle. None of the techniques is perfect, because it is not possible to measure directly how much milk a cow would have produced if mastitis had not occurred during lactation. All of the techniques have a degree of inherent bias, which, in most cases, tends to underestimate the actual milk production loss that has occurred (de Graves and Featrow, 1993). Nevertheless, there is scientific agreement that milk yield losses account for the main economic loss from sub-clinical mastitis. Schepers and Dijkhuizen (1991) noticed that changes in milk production was the only item included in estimates of all the previous papers analysed that dealt with economics of mastitis.

Estimates of milk yield loss remain a big issue because they are likely to be influenced by the age, breed and type of cow, morphological characteristic of the udder, stage of lactation, milk yield before mastitis occurred, mastitis-causing organisms, inflammation grade, diagnosis (early or late after occurrence), type of treatment, feeding practices, season, recurrence of mastitis during the same or previous lactation, comparison model (control group) and the analytical model.

For example, some mastitis causal agents were shown to have a more profound impact on milk yield than others. Thus, mastitis caused by *S. aureus* generally evolves into persistent but moderate infection, unlike mastitis caused by coliforms (Lescourret and Coulon, 1994; Petrovski, Trajcev and Buneski, 2006). Generally, it is estimated that the greater the inflammation the less milk the produced (Petrovski, Trajcev and Buneski, 2006).

Several approaches are available to estimate milk production loss due to mastitis:

- Comparing the performance of an infected quarter with the performance of the opposite uninfected one, as, in general, it is accepted that the contralateral quarters of the udder, when both are uninfected, give approximately the same volume of milk. At the same time there is scientific evidence that mastitis-free quarters may compensate for quarters with mastitis by increasing milk production. If compensation occurs this would cause overestimation of the actual milk loss as a result of mastitis (de Graves and Featrow, 1993; Petrovski, Trajcev and Buneski, 2006).

- Comparing the present lactation with the previous lactation for the same animal.
- Comparing production from an infected cow with that from an uninfected animal (de Graves and Featrow, 1993). This technique, also termed the between-cow comparison model, is affected by some non-mastitis compounding factors (age, breed, lactation number, etc.) and the cows must be closely matched for such factors (Petrovski, Trajcev and Buneski, 2006).

Matching of cases and controls was considered to have the following advantages:

- within farm, to attempt to minimize the effects of environmental and management factors;
- within the same lactation number, to minimize differences in total milk yield due to different lactation numbers; and
- within a certain range of days in lactation to neutralize changes in the lactation curve during production, taking into account that differences in daily milk yield, within a short period, will be greater around lactation peak than at the end of lactation.

A disadvantage of paired matching is the loss of valuable information owing to the impossibility of matching every case with an appropriate control (de Graaf and Dwinger, 1996).

Milk somatic cell count (SCC) has been used extensively as an indicator of intramammary infection since the 1960s, and SCC has been included as a component of the definition of mastitis (Pyorala, 2003).

The effects of an elevated SCC on milk production were reviewed by Hortet and Seegers (1998) in order to help the assessment of economic losses caused by sub-clinical mastitis. Elevated SCC levels in individual milk samples were found significantly associated with a loss in milk yield. The loss increased as SCC level increased. The average magnitude of loss in milk yield with increasing SCC was lower in primiparous than in multiparous cows. The mean loss at test day calculated was of about 0.5 kg per two-fold increase of SCC (0.4 kg in primiparous and 0.6 kg in multiparous animals) starting at over 50 000 cells/ml.

Production losses due to clinical and sub-clinical mastitis are generally considered a log-linear relationship between SCC and test-day records (Halasa *et al.*, 2007). St Rose and co-workers (2003) stress that milk production does not improve after complete recovery from sub-clinical mastitis, even after antibiotic therapy; the absence of increase in milk production in treated animals suggests that milk-secreting tissue did not return to normal, possibly because of involution and fibrosis of udder tissue, resulting in loss of secretory epithelium (St Rose *et al.*, 2003). Thus the assumed log-linear relationship might underestimate production losses due to sub-clinical mastitis.

Discarded milk

Because of treatment of a clinical case, milk has to be discarded during the treatment days and waiting time. In general, it is assumed that milk had to be discarded for 6 days: 3 days treatment and 3 days withholding period (Huijps, Lam and Hogeveen, 2008).

Treatment costs

There are two elements of the treatment cost: veterinarian fees and the cost of drugs. Obviously these two costs vary between countries.

Labour costs

Costs of labour are difficult to analyse. Opportunity costs of labour may differ from farm to farm. If the labour is external, then the cost of labour for the time that has been used to prevent mastitis is quite easy to calculate (hours × hourly wage). In contrast, if the labour comes from the farmer it is important to note that farmers could spend less time on other management tasks because of mastitis, so the opportunity costs are the decrease in income due to skipping these tasks (Halasa *et al.*, 2007).

Premature culling and replacement

Culling is a decision of the dairy farmer. Generally, a cow is culled when replacement is the optimal decision. Cows with mastitis have a higher risk of being culled, and the cost of premature replacement of animals due to mastitis is, probably, one of the largest areas of economic loss (Halasa *et al.*, 2007; Petrovski, Trajcev and Buneski, 2006; de Graves and Featrow, 1993; Hortet and Seegers, 1998). The direct costs are the cost of rearing or buying a replacement animal. At the same time there are returns from culling a cow, mostly the price of the meat. Indirect costs could be decreased efficiency of milk production by the replacement animal, as usually a multiparous cow is more productive than a primiparous one (Halasa *et al.*, 2007).

One means, proposed by Singh and Singh (1994), to assess the economic loss due to culling of a mastitic animal is to calculate the average price of lactating animal minus price received for culled animal, and the replacement value of a new animal is given by the sum of the average price of lactating animal + loss incurred by culling a mastitic animal. To calculate the total loss due to culling the mastitic animals and their replacement it is necessary to know the culling rate, which is information generally not available. This method does not consider the indirect costs mentioned by Halasa *et al.*, (2007).

Lethality and occurrence of other diseases

Only a few papers deal with the topic of mastitis lethality. Seegers, Fourichon and Beaudeau (2003) reported two studies from France and Ireland that calculated a mastitis-attributable annual mortality rate of 0.22% (Faye and Pèrochon, 1995) and 0.19% (Menzies *et al.*, 1995). The main pathogens involved were *E. coli*, *Klebsiella* spp. and *S. aureus*.

An important consideration in the assessment is that many farmers do not consider losses due to disease that does not induce animal mortality (Ravaomanana *et al.*, 2004). Furthermore, it is important to bear in mind that mastitic cows are a constant source of contagion due to shedding of bacteria (Halasa *et al.*, 2007).

What farmers may not notice, and may not be aware of, is the indirect cost stemming from reduced reproductive performance. Studies confirm that mastitis has detrimental effects on reproductive efficiency of dairy cows and thus negatively affects the profitability of dairy herds. Several studies investigated the differences between cows affected by clinical mastitis and uninfected cows, and showed that clinical mastitis alone affected reproductive performance by increasing days open and services per conception (Ahmadzadeh, McGuire and Dalton, 2010).

ECONOMIC EFFECTS OF MASTITIS ALONG THE VALUE CHAIN

Access to market is one of the pre-conditions for livestock development, and economic growth among resource-poor livestock keepers will depend on their level of access to markets for their livestock produce (IFAD, 2004). Analysis of mastitis impact along the dairy value chain must be addressed to avoid underestimating the impact of the disease, through analysis of the disease at different levels, not only farm level but possibly also at the milk collecting points, or at processor level.

It is scientifically proven that mastitis causes alterations that affect milk quality directly through changes in technical and hygienic milk quality, resulting in less efficient processing of milk, which might result in products with less favourable properties. When mastitic milk is used for manufacturing, common product defects include increased coagulation times and reduced cheese yields, extended churning times for butter, altered heat stability of powders, and reduced shelf life and/or organoleptic properties of many products (Auldist, 2011).

ESTIMATES OF THE COST OF MASTITIS IN DIFFERENT DEVELOPING COUNTRIES

Very limited published data are available to quantify production losses and expenditures related to mastitis in developing countries, and thus to assess the economic impact of the disease.

Furthermore, different methods are used to calculate the financial losses due to the disease and so it is difficult to compare results. Because production systems, environment, management and breeds are different, it is not possible to compare data from developed and developing countries, nor to refer data collected in developed countries to developing ones. So there is the need to assess the extent of financial losses due to mastitis on the basis of studies conducted in the developing countries.

Below are considered some studies from different countries, addressing the topic of economic impact of mastitis. Note that the methods used to calculate the financial losses are different.

Ethiopia

The first studies conducted in Ethiopia on the topic of mastitis economic impact aimed to assess milk yield losses due to the disease, with the awareness that milk production losses accounted for 78% of the total losses caused by mastitis (Schepers and Dijkhuizen, 1991). Very limited published data were available to quantify milk production losses associated with SCM under tropical conditions. The study aimed to fill that gap.

A split-udder trial was carried out to determine milk yield losses in udder quarters with sub-clinical mastitis (Mungube *et al.,* 2005) and, more specifically, with sub-clinical mastitis caused by *S. aureus* (Tesfaye, Regassa and Kelay, 2010) under tropical conditions, rather than using the findings published for Western Europe and North America conditions (Dobbins 1977; de Graves and Featrow 1993). Each quarter of the study cows was examined using CMT, and quarter milk production was measured (for a period of 8 days). The results are shown in Table 5.

Table 5. The distribution of quarter CMT scores and milk production losses

	CMT 0	CMT 1	CMT 2	CMT 3	Total Loss %
Loss % *	0	1.2	6.3	33.0	
No. of cows	945	128	115	210	5.6

Notes: *To estimate milk production losses, the average milk yield was considered to be 8.8 kg/day per crossbred dairy cow.
Source: Mungube *et al.*, 2005.

In the population included in the study, production losses due to sub-clinical mastitis per subsystem level (Pl_y) or at farm-size level were determined by the formula:

$$PL_y = \frac{CMT_0 * PL_{CMT0} + CMT_1 * PL_{CMT1} + CMT_2 * PL_{CMT2} + CMT_3 * PL_{CMT3}}{CMT_{0y} + CMT_{1y} + CMT_{2y} + CMT_{3y}}$$

where: $PL_{CMT\,0,1,2,3}$ = Production losses determined in the split-udder investigation; and

$CMT_{0y,1y,2y,3y}$= Number of quarters with the respective CMT score in the sub-system.

The production systems investigated were urban dairy farms, peri-urban dairy farms and dairy herds in secondary towns. A total loss of US$ 38 per cow per lactation was estimated (based on an average price of 2.0 Ethiopian Birr per kg of milk).

Madagascar

Countrywide, milk production is based on small-scale dairy farms and cows are milked manually. The average milk yield in Madagascar for the period 2004–2010 was 304 kg/cow/year (FAOSTAT data). The first effort to quantify the economic impact of mastitis on small-scale production dates from 2004 (mean herd size per farm: 4 cows) in the 20-km peri-urban zone of Antanarivo. Results recorded a prevalence of 79% SCM and 9% CM, using CMT (Ravaomana *et al.*, 2004).

The combined annual cost of losses and expenditures relative to CM, calculated by the modified formulae developed by Thirapatsakun (1989), reached US$ 188 per cow (2001 Malagasy price conditions). Unfortunately, no data were calculated for the economic impact of sub-clinical mastitis. The authors reported also a general lack of awareness among farmers that the costs due to mastitis were so high.

The formulae used to calculate the economic losses were:

Financial loss due to CM per cow: $Em= [P/NL+(L \times kg \times B)] \times M/4$

Financial cost of each treatment of a mastitis case per cow:

$$Et= M\,x[C+(Im+In/M)D]+A$$

Where:
P = Cow value
NL = Number of Lactation

L = days with no milk delivered
kg = average daily milk production
B = Price per kg raw milk
M = Number of affected quarters
C = Cost of bacterial culture
Im = Cost of 1 intra-mammary infusion syringe
In = Cost of 1 systemic injection
D = Days of treatment
A = Miscellaneous expenditures

India

The first effort to assess the economic impact of mastitis in India was carried out by Dhanda and Sethi in 1962. They reported a financial loss of Rs. 52.9×10^7 per year due to mastitis (111 million USD of 1962).

This data was updated in 1994 by Singh and Singh, who conducted the first reported study to calculate the economic losses due to mastitis on scientific lines, in cows and buffaloes under separate categories of sub-clinical and clinical mastitis.

Sub-clinical mastitis:

They calculated the milk production loss due to SCM per animal in one lactation using the formula:

Milk losses per animal per lactation = Average milk loss due to sub-clinical mastitis (%) × Average lactation yield of animal × Average price of milk (with average milk loss taken as 17.5%).

The total loss due to SCM (milk loss due to SCM per animal per lactation × number of animals affected with SCM) was Rs. 603.87×10^7 for cows (192 million USD of 1994) and Rs. 483.10×10^7 in buffaloes (154 million USD of 1994).

Clinical mastitis:

The calculations for losses due to CM (economic loss due to reduced milk production) also included the cost of milk discarded due to clinical mastitis, veterinary consultation charges + cost of medicines (average estimate).

Economic loss due to reduced milk production = Average milk loss due to CM (%) × average daily milk yield of animal × average price of milk × average duration of a mastitis case.

Cost of milk discarded due to CM per animal = 0.50 × average daily milk yield of animal × average price of milk × number of days milk is discarded.

Total losses incurred during clinical mastitis by one cow or buffalo were calculated as the sum of reduced milk production + medicine + veterinary consultation charges + cost of discarded milk.

For the milch animal population, with an estimated average incidence of CM of 6.40 in cows and 3.84 in buffaloes, the annual financial losses due to the clinical form in India were Rs. 285.64×10^7 in cows (91 million USD of 1994) and Rs. 234.59×10^7 in buffaloes (75 million USD of 1994).

Milk and milk products have the potential to transmit pathogens to humans. The presence of food-borne pathogens in milk is due to direct contact with contaminated sources in the dairy farm environment and/or to excretion from the udder of an infected animal. All the nutritional components that make milk and milk products an important part of human diet also support the growth of pathogenic organisms (Oliver, Jayarao and Almeida, 2005). In cases of severe CM, abnormalities of milk are observed and milk is discarded by the producer. Such milk normally would not enter the food chain. But when milk of cows with SCM (no visible changes) is mixed into bulk milk, it enters the food chain and can be dangerous to humans (Hameed, Sender and Korwin-Kossakowska, 2007).

EFFECTS ON MILK COMPOSITION AND QUALITY

Mastitis not only negatively affects milk yield production, as discussed above, but has a negative impact also on milk composition and its physico-chemical characteristics.

These alterations are attributed to changes in vascular permeability due to the inflammatory process and the damage of epithelial cells that are responsible for the synthesis of milk components, as well as changes in the enzymatic action of somatic cells or micro-organisms in the infected mammary gland (Kitchen, 1981).

For lactose, Bansal *et al.,* (2005) determined that lactose content was higher in healthy quarters than in quarters with high SCC. This result is in agreement with other studies (Pyorala, 2003; Jones, 2006; Ogola, Shitandi and Nanua, 2007; Malek dos Reis *et al.,* 2013).

Casein, the major milk protein of high nutritional quality, declines and lower quality whey proteins (which derive from the blood mammary barrier disruption) increase, which together adversely affects dairy product quality, such as cheese yield, flavour and quality.

For minerals, because of the increasing vascular permeability and the damage caused by the inflammatory process, blood-borne electrolyte concentrations in milk change. Na^+ and Cl^- increase in mastitic milk, while K^+, normally the predominant mineral in milk, declines. Because most calcium in milk is associated with casein, the disruption of casein synthesis contributes to lowered calcium in milk (Jones, 2006).

These alterations affect milk quality directly through changes in technical and hygienic milk quality, resulting in less efficient processing of milk, and might result in products with less favourable properties. Examples are unstable and rancid taste of milk, a lower cheese yield and a decreased shelf life, which means economic damage to the dairy industry (Hogeveen, 2005). Mastitis can be a threat to human health due to bacterial contamination. Some mastitic milk carries bacteria that can cause severe human illness. Pasteurization reduces the number of viable micro-organisms but often does not destroy toxins produced by bacterial pathogens, hence the concern when raw milk is consumed or when pasteurization is faulty. The transfer of heat-stable toxins produced by mastitis-causing pathogens in milk is another serious potential concern (Hogan, 2005).

A pathogen that is found frequently in bulk tank milk and is a significant cause of mastitis in dairy cows throughout the world is *Staphylococcus aureus*. The bovine mammary gland can be a significant reservoir of enterotoxigenic strains of *S. aureus*. Enterotoxins produced by enterotoxigenic strains of *S. aureus* have frequently been implicated in cases of food poisoning (Hogan, 2005). Even if there are not precise data on the occurrence of food poisoning outbreaks due to *S. aureus* in developing countries, it must be remembered that this bacteria is one of the most commonly isolated mastitis-causing pathogens in the majority of the studies reviewed. In informally marketed bovine milk in Ethiopia, it was isolated in 44% of raw milk samples (Desissa *et al.,* 2012).

Last but not least, antibiotic residues is a mastitis related public health concern when antibiotics are used in an improper way in the treatment and control of the disease and withdrawal time is not applied. Antibiotics can lead to severe reactions in people allergic to antibiotics, and development of antibiotic-resistant strains of bacteria (Hameed, Sender and Korwin-Kossakowska, 2007).

Considerations of the multifaceted impact of mastitis on small-scale producer households

Livestock play an important role in the lives and livelihoods of more than 600 million of the poorest people on earth. Livestock are an essential asset to the rural poor, both to those directly engaged in agricultural production and to poor non-farm rural households who rely on local production for affordable nutrition. In most countries of SSA, dairy production is dominated by small-scale producers (Muriuki and Thorpe, 2006).

Similarly, the livestock sector in the South Asian countries is characterised by the preponderance of small-scale producers typically possessing only one or two milch animals, low productivity, lack of proper feeding and animal health care, an inadequate supporting infrastructure for supply of feed and veterinary medicines, procurement, processing, storage, transport and marketing of milk (Singh and Pundir, 2001). Thus small-scale systems constitute the core of the dairy sector in most developing countries, and a production disease like mastitis is undoubtedly a severe constraint not only at farm level but also in national dairy sector development.

Small-scale farms support the families who own them and provide extra food for local communities. Livestock contribute to food availability, access and stability. In some cases, direct provision of food is their primary contribution, while, in others, the main motivation for keeping them is income.

Generally, household nutrition levels through livestock keeping can be influenced in three ways:

- using the income from milk, manure or animal sale to buy food;
- direct use of products like milk and milk products; and
- using manure to improve household food production, such as vegetable and other food crop production.

So it is evident, as discussed in this paper, that mastitis is a disease with clear negative impact on small-scale producer households, not only in terms of financial losses but also because it is a source of unsafe milk. In fact, milk from affected animals can be a threat to human health, especially if consumed by vulnerable people (children, pregnant, old people, people living with HIV-AIDS), and if it is consumed raw or not properly pasteurized.

PERCEPTION AND AWARENESS OF THE IMPORTANCE OF THE DISEASE

Lack of knowledge and awareness are both undoubtedly the most important risk factors contributing to intra-mammary infection, but are difficult to quantify. Knowledge and awareness of mastitis influences farmer perceptions and decisions, which in turn will affect preventive and treatment regimes, such as post-milking teat disinfection, dry cow therapy, hygiene, ventilation, feeding, milking, housing and bedding.

Kivaria (2006) stated that one of the major concerns related to mastitis in Tanzania is that farmers and herd attendants need to improve their level of knowledge, attitude and motivation towards udder health. Farmers were asked whether they had ever seen udder diseases in lactating cows and it was recorded that 80% of farmers were aware of clinical mastitis in lactating cows and 83.7% of the farmers were also aware that mastitis not only reduces the quantity of milk but also its quality. But

lack of awareness of sub-clinical mastitis was apparent among the owners: only 5% of the owners interviewed were aware of the presence of sub-clinical mastitis. Further, risky management practices were recorded, as 33.3% of the farmers did not treat the mastitic cases, and 96% did not use dry cow therapy because they believed that if they used it, the cow would produce less in the subsequent lactation.
Other important risky behaviours, which contribute to antibiotic resistance, were the lack of observance of the full course of antibiotic treatment or the habit of changing therapy, in an inappropriate manner, if the clinical cases did not improve fast enough (Kivaria, 2006).
Another study conducted by Karimuribo and co-workers (2000) investigated farmer awareness of mastitis in the Southern Highlands of Tanzania, through a structured questionnaire. It was recorded that 62.1% of the farmers were aware of clinical mastitis and 28.6% had clinical mastitis cases, based on clinical signs recognizable by farmers. Of the farms which had clinical mastitis, 28.9% did not treat the disease, and the main reason they did not treat it (60%) was because they were not aware that the clinical signs described referred to mastitis.
In Pakistan, farmer perceptions about disease prevalence was investigated in three different areas using a Participatory Rural Appraisal approach, and the average prevalence related to mastitis was 24.3% (Ghaffar, Khan, and Ullah, 2007), even if it was not possible to compare this evidence with real prevalence determined by scientific data. It is interesting to note that among farmers, mastitis was the disease with the highest average prevalence reported.

A first goal of animal health economics is to create awareness of the costs associated with the disease. Perception refers to what a farmer thinks the economic losses of mastitis are on their farm. Farmer perceptions can deviate from the real situation. In the Netherlands, a developed country with a strong dairy sector, Huijps, Lam and Hogeveen (2008) recorded that most farmers included in his study underestimated the cost of mastitis for their farm business.

Hence, even if mastitis is worldwide described as the most expensive production disease, farmers do not always perceive mastitis as being expensive, or they underestimate its cost (de Graves and Featrow, 1993; Ravaomana *et al.,* 2004).

Due to the chronic nature of mastitis, economic damage is spread over the year. Moreover, the most important cost factors, such as decreased milk production and major risk of culling, are not directly visible, whereas control costs are highly visible (de Graves and Featrow, 1993).

By calculating the cost of mastitis, awareness of the economic losses can be increased, and this may lead to an increase in the motivation of dairy farmers to consider improving udder health on their farms (de Graves and Featrow, 1993; Huijps, Lam and Hogeveen, 2008; Kivaria, 2006; Hogeveen, Huijps and Lam, 2011).

Discussion and conclusions, statement and future perspective

Livestock production makes an important contribution to economic development, rural livelihoods, poverty alleviation and meeting the fast growing demand for proteins of animal origin in developing countries.

About 1 billion poor people depend entirely or partially on livestock for their livelihood, and in most developing countries livestock keepers are small-scale producers.

The existing literature on mastitis in developing countries provides evidence that the disease is a constraint for small-scale producer development due to its high prevalence, which in some herds reaches 80-90% at animal level.

The negative impact of the disease is well known in industrialized countries but, even if estimating the costs associated with mastitis is notoriously difficult, in most developing countries there is lack of scientific data on mastitis-associated economic costs, both at farm and at national levels.

Because of different management systems, breeds, climate and other features, it is not possible to extrapolate to developing countries data from studies conducted to assess the financial losses due to mastitis in industrialized countries.

Thus, there is need to quantify the economic impact of the disease in developing countries on a scientific basis, aware that mastitis is a heavy economic burden in the dairy sector of developed countries, and, with its high occurrence in developing countries it can be a serious constraint on the development of the dairy sector in resource-poor environments.

Moreover, the huge comparative differences between different methods of assessing economic losses due to mastitis highlight the need for establishing internationally accepted guidelines for methods by which losses due to mastitis and the costs and benefits of control programmes can be estimated.

As discussed in numerous studies, to be able to consider the real cost of mastitis, the prevalence and incidence should first be established. Then estimation of all relevant costs and expenditures should be made, and the last step will be to include all of them in a large model for mastitis cost estimation.

Furthermore, it is well known that mastitis is not only a financial constraint at farm level, but it has a lot of overlapping issues (such as the effect on milk quality) whose quantitative assessment requires considerable effort.

In fact, because a significant portion of milk produced by small-scale producers is for self-consumption, the nutritional dimension of mastitis is an important factor in public health, especially in countries in which the population has to cope daily with hunger and malnutrition. Even if the costs of human diseases are difficult, if not impossible, to calculate, this aspect cannot be ignored.

Lastly, mastitis is an endemic disease and so it requires broad-based effort to control and decrease its occurrence.

Knowledge and awareness of risk factors and characteristics of mastitis causing pathogens involved are essential to control the wide spread of the disease at farm level. Although the use of SCC has increased as a means of milk quality control and udder health in industrialized countries, this technique has not yet been adopted in many countries in the tropics.

As the high prevalence of sub-clinical mastitis in dairy herds presents a major constraint to high quality milk production, adoption of SCC for use in quality control is very important. Understanding the financial losses caused by the disease and its negative impact on milk quality can be the first step in highlighting the importance of mastitis and in developing control programmes.

A nation-wide prevention and control programme, able to also reach marginal geographical areas, is required to control in an efficient way the disease at national level. It is important to realize that in some countries, production-related diseases such as mastitis are given little attention in the national health control scheme, although they have been reported to be highly prevalent in the small-scale dairy sector.

To summarize, there is lack of information on the economic impact of the disease in the majority of developing countries; lack of awareness among farmers concerning sub-clinical mastitis and the importance of udder health; and lack of specific national programmes to control mastitis in the majority of countries. All these imply a need for concerted future effort to control mastitis.

The data collected and organized in this paper can be used as a starting point to concentrate future efforts on the study and control of the impact of mastitis in developing countries, with a focus on its relevance for vulnerable small-scale producer households.

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