Animal (2019), **13:11**, pp 2650–2659 © The Animal Consortium 2019
doi:10.1017/S175173111900082X

Failure costs associated with mastitis in smallholder dairy farms keeping Holstein Friesian × Zebu crossbreed cows

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(Received 13 September 2017; Accepted 19 March 2019; First published online 16 May 2019)

*Mastitis is a costly disease and in many areas of the world, these costs have been quantified to support farmers in their decision making with regard to prevention of mastitis. Although for subsaharan circumstances estimates have been made for the costs of subclinical mastitis (**SCM**), farm-specific cost estimations comprising both clinical mastitis (**CM**) and SCM are lacking. In this paper, we quantified failure costs of both CM and SCM on 150 Ethiopian market-oriented dairy farms keeping Holstein Friesian × Zebu breed cows. Data about CM were collected by face-to-face interviews and the prevalence of SCM was estimated for each farm using the California mastitis test. All other relevant information needed to calculate the failure costs, such as the consequences of mastitis and price levels, was collected during the farm visits, except for the parameter for milk production losses due to SCM, which was based on literature estimates and subjected to sensitivity analyses. The average total failure costs of mastitis was estimated to be 4 765 Ethiopian Birr (**ETB**) (1 ETB = 0.0449 USD) per farm per year of which SCM contributed 54% of the costs. The average total failure costs per lactating cow per farm per year were 1 961 ETB, with a large variation between farms (range 0 to 35 084 ETB). This large variation in failure costs between farms was mainly driven by variation in incidence of CM and prevalence of SCM. Milk production losses made the largest contribution (80%), whereas culling contributed 13% to 17% to the total failure costs. In our estimates, costs of veterinary services, drugs, discarded milk and labour made a minor contribution to the total failure costs of mastitis. Relative to the income of dairy farmers in North Western Ethiopia; the total failure costs of mastitis are high. In general, Ethiopian farmers are aware of the negative consequences of CM, but creating awareness of the high costs of SCM and showing large variation between farmers may be instrumental in motivating farmers to also take preventive measures for SCM.*

Keywords: clinical mastitis, dairy, failure cost, smallholder farms, subclinical mastitis

Implications

This study estimates failure costs of mastitis in small holder dairy farms, quantifies the between-farm variation and identifies the most important drivers of this variation. Herd health advisors can use these data to better interpret the economic consequences of farm-specific mastitis situations and motivate dairy farmers to implement mastitis control measures. Altogether, this will contribute to improved dairy cattle production efficiency resulting in improved farmer's income and their family's subsistence.

Introduction

Mastitis is a common production disease affecting dairy cows worldwide. In many countries and for many circumstances, it has been calculated how costly mastitis is to a farmer (Huijps *et al.*, 2008; Geary *et al.*, 2012; Guimarães *et al.*, 2017). Often, such studies estimate failure costs (costs resulting from having mastitis), rather than preventive costs (costs associated with prevention of mastitis) (van Soest *et al.*, 2016; Hogeveen and van der Voort, 2017). Estimating farm-specific failure costs is instrumental in motivating farmers to control mastitis and to support on-farm decision making as it helps evaluating the profitability of preventive measures (Heikkilä *et al.*, 2012).

Although many articles have been published on the costs of mastitis, specific information on mastitis costs in developing countries is limited. Of the 37 studies recently reviewed by Hogeveen and van der Voort (2017), only one was about a developing country (Getaneh *et al.*, 2017). As the management systems, income of farmers and other related features are different, generally, it is not possible to generalize the

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findings from studies conducted in industrialized countries to developing countries (Hogeveen and Østerås, 2005; Food and Agricultural Organization, 2014). So in order to get a better estimate of the costs of mastitis specifically for the situation in developing countries more estimates are needed. This can be done in a normative way, by adjusting the input of generic herd simulation models, such as SimHerd (Østergaard *et al*., 2005) or by building specific simulation models (Getaneh *et al*., 2017). Another approach is to estimate farm-specific costs of mastitis, based on data collected on farms. Dairy production is of great importance for the Ethiopian economy (Tangka *et al*., 2002). Urban and peri-urban dairy farmers serve as the major milk suppliers for the fast growing urban milk market (Gebre-Wold *et al*., 1998; Ayenew *et al*., 2009). In Ethiopia, mastitis is a common problem on dairy farms. Farmers often notice cases of clinical mastitis (**CM**), but generally are less aware of subclinical mastitis (**SCM**), despite its high prevalence (Almaw *et al*., 2008; Tolosa *et al*., 2015). Data in one of our previous studies show that unlike their knowledge on CM only seven of 151 dairy farmers in Ethiopia were familiar with SCM (Mekonnen *et al*., 2017). Good estimates of mastitis costs, including costs of SCM may help motivate farmers to take preventive mastitis management measures. Particularly, the estimation of farm-specific costs can be helpful, as it provides farmers with a benchmark against which to assess their own situation.

The costs of mastitis are not well studied in Ethiopian dairy farms or for other subsaharan countries. Two Ethiopian studies have been published on the economic impact of SCM: Mungube *et al*. (2005) reported a financial loss of US$38 and Tesfaye *et al*. (2010) reported US$79 per cow per lactation. In these studies, the calculation was based on a relatively old estimation (1985) of milk yield at the early days of cross-breeding of Holstein Friesian × Zebu breed cows (Mekonnen *et al*., 1985). In the meantime, the average milk yield of cross-breed cows has increased because of increased Holstein Friesian blood level, resulting in higher milk yield, but likely also in increased prevalence of SCM, as the Holstein Friesian blood level was found to be positively associated with SCM prevalence in Ethiopia (Mekonnen *et al*., 2017). In addition, costs related to CM such as costs related to treatment, culling and labour in managing sick cows have, in previous studies, not been included despite the fact that these costs are expected to be substantial. Recently, the total costs of CM and SCM were estimated for Ethiopian market-oriented dairy farms by using a normative bio-economic simulation model (Getaneh *et al*., 2017), using available knowledge from the literature. Because hardly any data from Ethiopia were available, almost all parameters had to be based on knowledge from other countries and experts' opinions (Getaneh *et al*., 2017). Moreover, although a normative study with limited data can give insight in the average costs of mastitis, insight in the real farm-to-farm variation in costs is difficult to obtain with such models. Additionally, mastitis control programs are not yet developed in Ethiopia. Management measures to prevent mastitis are rarely implemented, and to obtain data on costs associated with these preventive measures is very difficult. By calculating the failure costs of mastitis, awareness of the financial consequences of mastitis can be created. Consequently, the possibility of financial returns from improving udder health can be illustrated, which is a first step for udder health control and an important part of farmers' motivation to improve udder health.

In this study, we collected the farm-specific parameters needed to calculate per-farm failure costs of mastitis through questionnaires and by testing individual cows for SCM on 150 farms. Our aims were to estimate the average total failure costs of mastitis in North-Western Ethiopian urban and peri-urban dairy farms and to quantify the between-farm variation in these costs.

Material and methods

Studied herds and sampling design

The studied herds kept Holstein Friesian × Zebu breed cows. The herds were selected from a list of urban or peri-urban dairy farms in the area of Bahir Dar and Gondar in North-Western Ethiopia. By collecting lists of dairy farms from artificial insemination records, from dairy cooperatives, and from veterinary clinics, a long list of 1 209 dairy farms from Gondar and of 272 from Bahir Dar was made. Computer generated random numbers were assigned, stratified for Gondar and Bahir Dar, to all farms on the long list. Farms were enrolled in the order of the assigned random numbers.

If a farmer was not willing to participate in the study, had stopped dairy farming, if the farm could not be found or if a farm only had cows of indigenous breeds, that farm was skipped from the list and the farm with the next number was approached. For these reasons, 230 farms in Gondar and five farms in Bahir Dar were skipped. Finally, we could include a total of 150 farms, 89 from Gondar (27% of the listed farms) and 61 from Bahir Dar (26% of the listed farms). The studied herds and the sampling design have been described in more detail by Mekonnen *et al*. (2017).

Design of the questionnaire and on farm data collection

A questionnaire aiming to collect data required to estimate the farm-specific failure costs of mastitis was prepared based on literature and our own expertise. Questions were designed to collect data in such a way that farm-specific calculations of the failure costs of mastitis (after Huijps *et al*. 2008) could be made. Data included the average milk yield and lactation length, the occurrence of CM during the last year (365 days), the impact of mastitis on milk yield, treatments and the duration of treatments, the withholding periods, costs of veterinary service, costs of labour and costs of culling.

The order of the questions was carefully chosen in order to avoid leading questions. The original English questionnaire was translated to the farmers' local language (Amharic), and subsequently translated back into English by an external translator to validate the translation. Corrections were subsequently made to the translation based on the comparison of different versions. In addition, the questionnaire was tested by performing five pilot interviews in a convenience sample of farmers. Selection of participants and the data collection took place together with data collection for another study in which the data collection procedure was described in more detail (Mekonnen *et al.*, 2017). Two veterinary students interested to participate in the data collection were selected. These students were instructed about the purpose of the study and about the questions in the questionnaire by the first author. Specific attention was given to a consistent approach and questioning of the farmers. Pilot interviews were held with five farmers to test the consistency and clarity of the questions. The students attended the pilot interviews made by the first author. The actual interviewing and California mastitis test (**CMT**) was executed by the first author together with the two students. Data from 17 farms could not be used in the analysis, because the data from these farms were incomplete. Eventually, from 150 of the 167 farms enrolled in the study, the data were sufficient to calculate failure costs. Since there is no routine testing program for SCM in place, milk from each quarter of each cow was tested with the CMT. Quarter milk CMT scores were classified as negative (**0**), trace (**T**), weakly positive (**1**+), distinctively positive (**2**+), and strongly positive (**3**+), in accordance with National Mastitis Council (1999). A quarter was considered to have SCM if it scored trace (T), +1, +2 or +3.

Calculation of failure costs

Failure costs of mastitis were calculated based on the prevalence of SCM by the CMT score at quarter level and the incidence of CM obtained from the questionnaire, in combination with information obtained from the questionnaire and the literature. When a farmer did not have information on specific parameters, these were estimated. For instance, the quantity of discarded milk during treatment was estimated by assuming that all quarters of a cow contribute equally to the average milk yield of a cow and was furthermore based on the farmer's response on the number of quarters from which milk was withheld or discarded; the time that was spent in managing a sick cow was estimated by our experience to be 10 min per day; sick cows need special management for 5 days and animal attendants working time was estimated to be 10 h per day. Calculations were carried out at the farm level. The calculations were done, based on the framework described by Halasa *et al.* (2007) and the methodology used by Huijps *et al.* (2008), with the costs of SCM based on CMT scores. Costs of milk production losses due to CM, treatment (antibiotics, labour and discarded milk), veterinary visits and culling were summed to estimate the total failure costs of CM. As farmers did not have information on the effect of SCM on milk yield, we used data from a study conducted on crossbred dairy cows in Ethiopia (Mungube *et al.*, 2005), which showed that udder quarters with CMT scores of 1+, 2+ and 3+ had a reduced milk production of 1.2%, 6.3% and 33%, respectively, compared to CMT score 0. Data used to calculate the failure costs of mastitis and the calculation are available in Supplementary Material S1.

To estimate the total failure costs per farm, we made the following assumptions:

1. Because there is no routine testing of SCM in Ethiopia, we assumed a constant SCM prevalence at the herd level over the year, based on the single cross-sectional CMT measurement during the farm visit.
2. Milk production losses from quarters with a CMT score T and a CMT score 1+ were considered to be equivalent (Mungube *et al.*, 2005).
3. The value of milk suckled by calves while CM cows were not milked because of treatment and drug withdrawal was considered to be insignificant.
4. Only one quarter was assumed to be affected in a cow with CM.
5. Because parity of cows was generally unknown to the farmers, all CM cases were considered to occur in the same average parity.
6. Because dairy farmers did not have any cow records, lactation length was uncertain. Therefore, the failure costs of mastitis per lactating cow were estimated at an average lactation length (314 days).
7. If farmers could not estimate the duration of milk production losses due to CM after the drug withdrawal period, milk production losses due to CM were considered to last for half a lactation.
8. Milk production level was considered constant throughout lactation.
9. Losses in milk production due to CM and SCM were calculated independent from each other.
10. When a farmer had veterinary service from a governmental veterinary clinic as well as from a private veterinary service, it was assumed that half of the cases were treated by the government veterinary clinic and half by the private veterinarian.

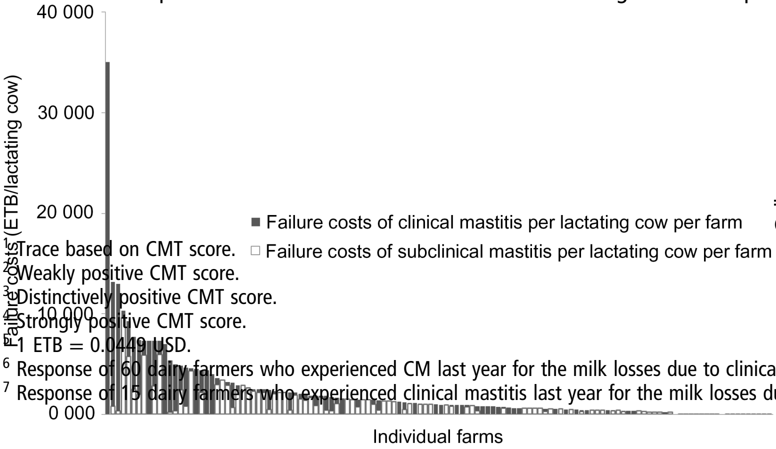
Costs of subclinical mastitis. The costs of SCM is estimated as:-

Table 1 *Descriptive statistics of model input parameters based on a questionnaire administered at 150 market-oriented dairy cow farms in North-Western Ethiopia*

Model parameters	5%	Average	95%
Number of quarters with CMT score T[1] and 1[2] per farm	0	2.04	7
Number of CMT score 2[3] per farm	0	0.87	3.6
Number of CMT score 3[4] per farm	0	0.54	3
Average daily milk yield per cow (kg)	5	10.4	18
Lactation length (days)	210	314	365
Price per kg of milk (ETB[5])	9	11.2	14
Treatment duration (days)	1	3.6	5.35
Number of clinical mastitis cases per farm	1	0.99	4
Drug withdrawal period (days)	3	4.8	7
Milk production losses per day due to clinical mastitis after drug withdrawal period (kg)[6]	0.5	1.75	4
Milk production losses per day due to clinical mastitis after drug withdrawal period (%)[7]	33	48	60
Duration of milk production losses due to clinical mastitis after drug withdrawal period (days)	3	58	195
	50	132	265
	23.25	64	123.5
(min)	30	96	180
	0	4	5.6
	5750	24642	35000
	12750	10500	16000

CMT = California mastitis test; ETB = Ethiopian Birr.

[1] Trace based on CMT score.
[2] Weakly positive CMT score.
[3] Distinctively positive CMT score.
[4] Strongly positive CMT score.
[5] 1 ETB = 0.0449 USD.
[6] Response of 60 dairy farmers who experienced CM last year for the milk losses due to clinical mastitis after drug withdrawal period.
[7] Response of 15 dairy farmers who experienced clinical mastitis last year for the milk losses due to clinical mastitis after drug withdrawal period.



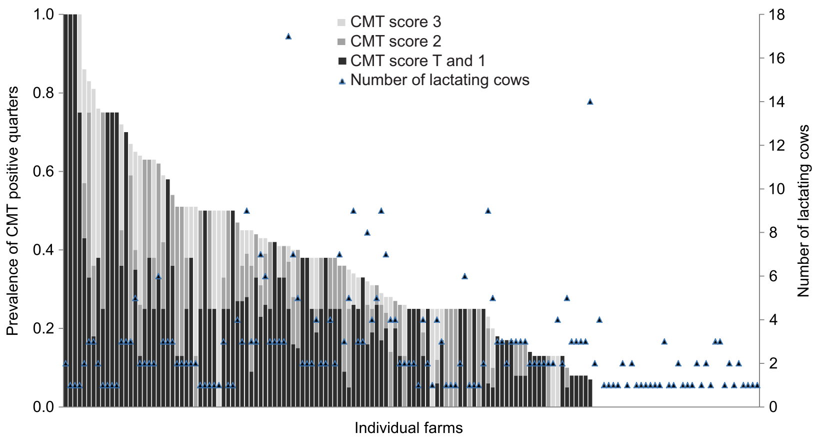
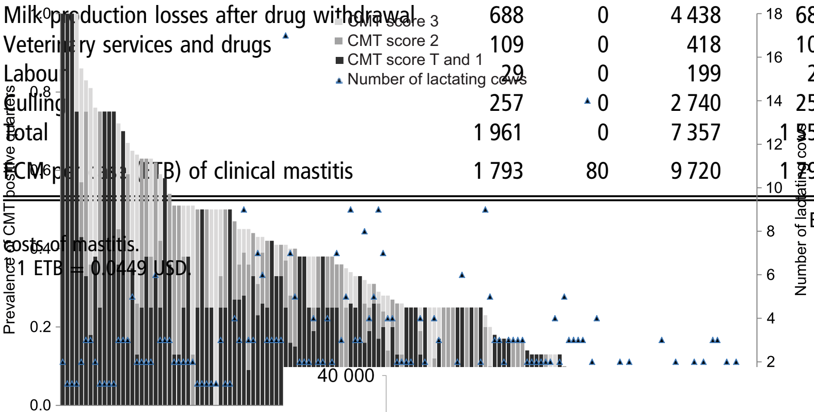


Figure 1 (colour online) The prevalences of quarters of positive CMT score T (trace) and 1 (weakly positive), CMT score 2 (distinctively positive) and CMT score 3 (strongly positive) in 150 market-oriented dairy cow farms in North-Western Ethiopia. CMT = California mastitis test.

Table 2 *Average farm-specific failure costs of mastitis in ETB[1] (1 ETB = 0.0449 USD) per farm per year and per lactating cow per farm per year at a baseline scenario and at a low milk production losses scenario, based on farmers' reported milk prices, and at an average milk price 11.20 ETB on 150 market-oriented dairy farms in North-Western Ethiopia*

	Calculation scenarios						Average milk price[3]		
	Baseline			Low milk losses[2]					
Cost factors	Average	5%	95%	Average	5%	95%	Average	5%	95%
FCM per farm (ETB/year)									
Subclinical mastitis	2 569	0	12 469	1 284	0	6 234	2 706	0	12 580
Clinical mastitis	2 196	0	5 680	2 196	0	5 680	2 206	0	12 123
Total	4 765	0	20 281	3 480	0	14 383	4 912	0	23 075
FCM per cow per farm (ETB/year)									
Subclinical mastitis	814	0	2 939	407	0	1 470	838	0	3 251
Milk production losses	814	0	2 939	407	0	1 470	838	0	3 251
Clinical mastitis	1 147	0	12 290	1 147	0	12 290	1 128	0	5 041
Withheld milk	64	0	236	64	0	236	61	0	230
Milk production losses after drug withdrawal	688	0	4 438	688	0	4 438	672	0	4 238
Veterinary services and drugs	109	0	418	109	0	418	109	0	418
Labour	29	0	199	29	0	199	29	0	199
Culling	257	0	2 740	257	0	2 740	257	0	2 740
Total	1 961	0	7 357	1 554	0	6 402	1 966	0	7 515
FCM per case (ETB) of clinical mastitis	1 793	80	9 720	1 793	80	9 720	2 151	76	11 088

[1]ETB = Ethiopian Birr; UDS = United States Dollar; FCM = Failure costs of mastitis.
1 ETB = 0.0449 USD.



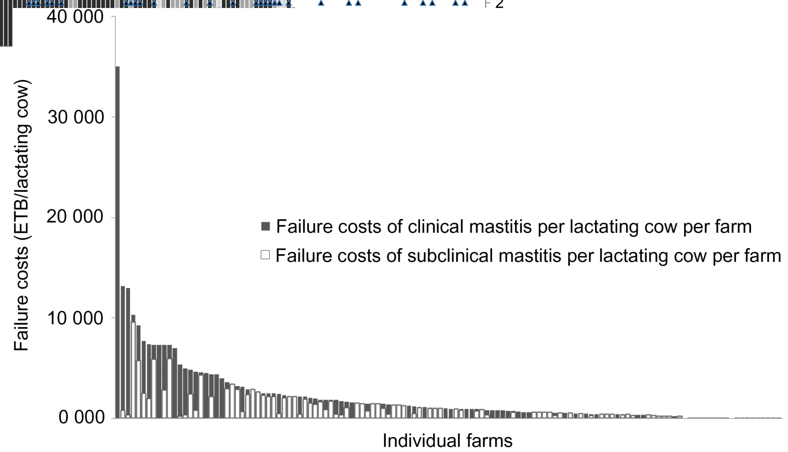


Figure 2 Failure costs of mastitis in ETB per lactating cow per farm summed for subclinical mastitis and clinical mastitis on 150 market-oriented dairy farms in North-Western Ethiopia. ETB = Ethiopian Birr.