J. Dairy Sci. 101:1–12
https://doi.org/10.3168/jds.2018-14824

Pathogen-specific production losses in bovine mastitis

A.-M. Heikkilä,*[1] E. Liski,* S. Pyörälä,† and S. Taponen†
*Natural Resources Institute Finland, Helsinki, Finland FI-00790
†Department of Production Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Finland FI-00014

ABSTRACT

Reduction in long-term milk yields represents a notable share of the economic losses caused by bovine mastitis. Efficient, economic, and safe measures to prevent these losses require knowledge of the causal agent of the disease. The aim of this study was to investigate pathogen-specific impacts of mastitis on milk production of dairy cows. The materials consisted of milk and health recording data and microbiological diagnoses of mastitic quarter milk samples of 20,234 Finnish dairy cows during 2010, 2011, and 2012. The 6 most common udder pathogens were included in the study: *Staphylococcus aureus*, non-*aureus* staphylococci (NAS), *Escherichia coli*, *Corynebacterium bovis*, *Streptococcus uberis*, and *Streptococcus dysgalactiae*. We used a 2-level multilevel model to estimate curves for lactations with and without mastitis. The data on lactation periods to be compared were collected from the same cow. To enable comparison among lactations representing diverse parities, the estimated lactation curves were adjusted to describe the cow's third lactation. Mastitis caused by each pathogen resulted in milk production loss. The extent of the reduction depended on the pathogen, the timing of mastitis during lactation, and the type of mastitis (clinical vs. subclinical). The 2 most commonly detected pathogens were NAS and *Staph. aureus*. *Escherichia coli* clinical mastitis diagnosed before peak lactation caused the largest loss, 10.6% of the 305-d milk yield (3.5 kg/d). The corresponding loss for *Staph. aureus* mastitis was 7.1% (2.3 kg/d). In *Staph. aureus* mastitis diagnosed between 54 and 120 d in milk, the loss was 4.3% (1.4 kg/d). The loss was almost equal in both clinical and subclinical mastitis caused by *Staph. aureus*. Mastitis caused by *Strep. uberis* and *Strep. dysgalactiae* resulted in losses ranging from 3.7% (1.2 kg/d) to 6.6% (2.1 kg/d) depending on type and timing of mastitis. Clinical mastitis caused by the minor pathogens *C. bovis* and NAS also had a negative effect on milk production: 7.4% (2.4 kg/d) in *C. bovis* and 5.7% (1.8 kg/d) in NAS when both were diagnosed before peak lactation. In conclusion, minor pathogens should not be underestimated as a cause of milk yield reduction. On single dairy farms, control of *E. coli* mastitis would bring about a significant increase in milk production. Reducing *Staph. aureus* mastitis is the greatest challenge for the Finnish dairy sector.
Key words: bovine mastitis, pathogen, milk yield, multilevel modeling

INTRODUCTION

Bovine mastitis mainly results from IMI, and is mostly derived from common udder pathogens such as staphylococci, streptococci, and coliform species (Ruegg, 2017). Mastitis results in substantial problems in terms of animal welfare, food safety, and profitability of milk production. Prevention is always the best measure to avoid the negative effects of mastitis. To develop efficient incentives for prevention, information on the true costs of all types of mastitis is needed. To be efficient, economic, and safe, prevention measures should be adjusted according to the causal agent because different approaches are needed to address different pathogens (Lago et al., 2011a,b; Down et al., 2013; Griffioen et al., 2016). Moreover, public health issues have become increasingly important in the milk industry because of the fear concerning antimicrobial resistance, which increases the pressure to reduce antimicrobial drug usage. Prevention and treatment of mastitis are the main reasons for antimicrobial drug use in the dairy industry (EMA-EFSA, 2017).

Economic losses due to mastitis include direct costs due to diagnostic testing, veterinary service, medication, discarded milk, and labor, as well as indirect costs associated with future milk production loss, reduced reproduction, and premature culling and replacement of mastitic cows (e.g., Santos et al., 2004; Hagnestam-Nielsen and Østergaard, 2009; Hogeveen et al., 2011; Rollin et al., 2015). The costs of preventive measures should also be considered in the total costs of mastitis (van Soest et al., 2016). The extent of economic loss var-

Received March 26, 2018.
Accepted June 16, 2018.
[1] Corresponding author: anna-maija.heikkila@luke.fi

ies significantly among countries, depending on factors such as milk price, treatment costs, and replacement costs (Halasa et al., 2007). Despite country-specific variation, long-term milk yield losses constitute a notable share of the economic losses attributable to mastitis (Seegers et al., 2003; Heikkilä et al., 2012; Liang et al., 2017). Because of evaluation difficulties, particularly for indirect costs, dairy farmers typically underestimate the costs of mastitis (Huiips et al., 2008). Moreover, costs such as the loss of future milk returns are difficult to gauge.

The estimated milk yield reduction caused by mastitis varies across studies due to differences in follow-up periods, estimation methods, cattle breeds, management, and so on. One reason for the variation in results is the use of different diagnostic methods or definitions for bovine mastitis and IMI (Andersen et al., 2010; Dohoo et al., 2011; Reyher and Dohoo, 2011). The lactation phase when the cow becomes infected is critical because milk losses are significantly greater in early than in late lactation (Hagnestam et al., 2007). High milk yield predisposes cows to mastitis (Oltenacu and Broom, 2010; Taponen et al., 2017) but the decrease in milk production may be greater than that in less-productive cows (Koivula et al., 2005). Clinical and subclinical mastitis have different effects on milk production as do different mastitis-causing pathogens. Milk yield losses resulting from clinical mastitis or high SCC have been studied widely (e.g., Rajala-Schultz et al., 1999; Hagnestam-Nielsen et al., 2009; Detilleux, 2018) but pathogen-specific research has been limited in scope. In some studies carried out in New York State dairy herds, data were categorized according to the causal agent into gram-positive and gram-negative groups and sometimes to the species level (Gröhn et al., 2004; Schukken et al., 2009a; Hertl et al., 2014). Pathogen groups causing the greatest losses were gram-negative species, coliforms, and streptococci. The pathogens causing the greatest losses differed between primiparous and multiparous cows (Hertl et al., 2014). Potential effects of minor pathogens on milk production are largely unknown. In the study of Hertl et al. (2014), clinical mastitis caused by CNS did not result in milk yield losses.

Pathogen-specific information is a prerequisite for detailed estimation of economic losses and tailored control of mastitis. Hence, information on the occurrence of different mastitis-causing agents in herds is needed. Milk sampling for bacteriological diagnostics from all or most clinical and subclinical mastitis cases would create routinely available data on different causal agents. Unfortunately, this practice remains limited in many countries where mastitis is treated empirically, and mostly without sampling (Griffioen et al., 2016). On dairy farms, pathogen information could be used to improve mastitis management (Samson et al., 2016). For scientific research, it would open new possibilities to identify pathogen-specific risk factors and effects of mastitis and facilitate development of responsible treatments for introduction on dairy farms.

In Finland, milk sampling in mastitis cases is routine. Most mastitic milk samples are analyzed in the laboratories of Valio Ltd. (Helsinki, Finland), where the results are recorded in a bacteriological database (Vakkamäki et al., 2017). Moreover, 70% of dairy herds and 80% of dairy cows participate in the Finnish dairy herd recording system, where abundant cow- and herd-specific information is stored (ProAgria, 2017). The aim of this study was to investigate pathogen-specific impacts of mastitis on milk production of dairy cows. We aimed to explain these effects under farm conditions where current mastitis control practices are followed. As such, the results can be utilized in our upcoming study on the pathogen-specific costs of mastitis and the profitability of preventive measures on dairy farms. The field data, where the microbiological database of Valio Ltd. was merged with the database of the Finnish dairy herd recording systems, comprised the materials of the study. Six common udder pathogens were included in the evaluation of reduction in milk yields.

MATERIALS AND METHODS

Data

The initial materials consisted of data from milk and health recordings and microbiological diagnoses of mastitic quarter milk samples from 93,529 cows during the years 2010, 2011, and 2012. The data are part of the broader data set described in Vakkamäki et al. (2017).

Data for cows fulfilling the following criteria were included in this study: (1) the cow was of Nordic Red or Holstein breed; (2) the data from 2010 to 2012 included information from at least 2 lactations of a single cow; (3) at least one of the lactations was free from IMI; (4) from each cow, 1 to 4 quarter milk samples were sent for microbiological analysis to the laboratory of Valio Ltd. only once, on the same day; (5) only one pathogen was detected in the milk samples from a cow; and (6) the pathogen detected was *Staphylococcus aureus*, non-*aureus* staphylococci (**NAS**, formerly described as CNS), *Escherichia coli*, *Corynebacterium bovis*, *Streptococcus uberis*, or *Streptococcus dysgalactiae*. The number of cows fulfilling these criteria was 20,580. After excluding the cows with missing values, the numbers of cows and herds providing data for the study were 20,234 and 3,953, respectively. The pathogen frequencies among