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A 100-Year Review: Mastitis detection, management, and prevention[1]

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ABSTRACT

Mastitis is the most frequent disease of dairy cows and has well-recognized detrimental effects on animal wellbeing and dairy farm profitability. Since the beginning of modern dairy farming, producers have sought effective methods to minimize the occurrence of mastitis in their herds. The objective of this paper is to review and highlight important advances in detection, management, and prevention of mastitis that have occurred since the first volume of the *Journal of Dairy Science* was published in 1917. Initial research efforts were directed at understanding the nature of pathogenic bacteria that were responsible for most intramammary infections. For decades, researchers worked to identify effective strategies to control mastitis caused by *Streptococcus agalactiae* and *Staphylococcus aureus*. To develop successful control programs, mastitis workers first had to identify mechanisms of infection, define the clinical and subclinical states of the disease, discover appropriate screening tests, determine likely points of exposure, identify pathogen-specific characteristics, and develop effective procedures for machine milking. Pioneering researchers eventually recognized that mastitis control was based on preventing new infections from occurring in healthy cows and reducing the duration that cows remained infected. Development of a control program that incorporated post-milking teat dipping, hygienic milking procedures, and strategic use of antibiotic therapy at dry-off resulted in widespread control of contagious pathogens. As herd management changed, researchers were tasked with defining control of mastitis caused by opportunistic pathogens originating from environmental sources. As mastitis pathogens have evolved, researchers have sought to define antimicrobial usage that will maintain animal wellbeing while minimizing unnecessary usage. During the last century, tremendous significant advances in mastitis control have been made but changing herd structure and more rigorous processor standards ensure that mastitis will remain an important subject focus of future research.
Key words: mastitis, prevention, management, 100-year review, *Journal of Dairy Science*

INTRODUCTION

Historical evidence suggests that cows have been milked since at least 3100 BC (Nemet-Nejat, 1998) and it is likely that bovine mastitis has existed since that time. For millennia, the close contact required by hand milking allowed for easy detection of abnormalities of milk and the mammary gland, but little was known of the causes or management of mastitis. A more complete understanding of mastitis was not possible until the development of microscopes that allowed detection of microorganisms that are the primary etiological agents. The earliest mention of bovine mastitis in the *Journal of Dairy Science* (**JDS**) occurred in the third issue of 1917 and was focused on public health risks associated with high bacterial counts of raw milk. In that study, Breed and Brew (1917) described a method of grading dairy farms that included enumeration of bacteria in milk and noted that "long chain streptococci" were frequently found in large numbers, even when signs of inflammation were so slight that "farmers cannot be blamed for having saved the milk." The authors reported bacteriological results from several surveys of raw milk cans and noted in one survey (n = 9,387 cans), that >20% of "high count milk" could be attributable to "udder problems." During that period, streptococci were the primary known cause of mastitis and the concept of subclinical infections was just becoming known. Since then, pathogens, cows, and herd management have changed dramatically but mastitis remains an important disease of dairy cows. Hundreds of research and review articles with the topic of bovine mastitis have been published in JDS and the emphasis has broadened (Appendix Table A1). Effects of mastitis on public health, processing characteristics of milk, milk quality, animal wellbeing, and farm profitability have become well known. Quality standards for acceptable milk have progressed and concern about mastitis has expanded to include the effect of mastitis management programs on farm sustainability and consumer perceptions. The

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number of research articles in JDS that include content about mastitis has steadily increased from about 3 in 1917 to >100 in 2016. The purpose of this review is to highlight advances in detection, management, and prevention of mastitis with an emphasis on research published in JDS that has encapsulated our changing understanding of the disease.

DETECTION AND DIAGNOSIS

Pathogens Past and Present

In a comprehensive review, Plastridge (1958) noted that bacterial causes for mastitis were first advanced in the late 1800s. An early mastitis researcher (Murphy, 1947) defined a 3-phase process for development of mastitis based on (1) invasion of an organism (with or without establishment of infection), (2) infection (the bacteria became established in the gland), and (3) inflammation. This process continues to serve as the basis of our understanding of mastitis. Although numerous bacteria are recognized as able to cause IMI, initial emphasis of mastitis control was directed at pathogens that were known to spread among cows in a contagious manner when teats were exposed to bacteria in milk that originated from an infected mammary gland. For decades, *Streptococcus agalactiae* and *Staphylococcus aureus* were considered the most important contagious pathogens.

Streptococcus agalactiae and *Staphylococcus aureus*

Initial concern about bovine mastitis was based on public health and was directed at reducing bacterial counts of raw milk. Breed and Brew (1917) stated, "we have come to know that mastitis is a cause of high bacterial counts. The mastitis causing high bacterial counts has without exception been due to streptococci." As the dairy industry progressed, a broader understanding of mastitis pathogens emerged. In a manuscript titled "A study of flaky milk," Jones and Little (1927) reported observations of 20 instances where foremilk revealed "flocculent particles." Although streptococci were the most prevalent bacteria identified, hemolytic staphylococci (most likely *Staph. aureus*) accounted for 20% of bacterial pathogens, and only 1 case failed to yield significant bacterial growth. That paper contributed to our understanding of mastitis as they correctly defined the abnormalities observed in milk as clumping of leucocytes as a result of inflammation caused by IMI. Although occurrence of large numbers of bacteria in milk was an obvious public health issue, researchers noted that not all of the bacteria originated from IMI and that many aspects of mastitis remained obscure. By 1927, *Strep. agalactiae* was considered responsible for about 90% of IMI (Williams, 1927) and the subclinical condition was an important reason that milk was de-graded (from grade A to B). During this period, mastitis workers were struggling to find an efficient way to detect infected cows in order to maintain grade A status in infected herds (Williams, 1927). This issue remained important as the prevalence of IMI in the 1950s was estimated to approach 50% of cows and 25% of quarters (Plastridge, 1958). The emphasis on *Strep. agalactiae* as the most important cause of mastitis continued for several decades, although mastitis attributed to *Micrococcus pyogenes* (later defined as *Staph. aureus*) began to be recognized during the 1950s (Plastridge, 1958).

In 1956, at the annual meeting of the American Dairy Science Association, the committee on animal diseases reported that mastitis was "the most costly dairy cattle disease not under satisfactory control," (Murphy, 1956). In a seminal paper titled "Mastitis—The struggle for understanding," Murphy (1956) described years of experience with ineffective mastitis control programs in New York and Connecticut, and concluded that "the problem is larger than any single effort put forth toward its understanding." He then presented 8 points to help define the disease (Table 1). These points serve as the basis of our modern understanding of the disease and succinctly define the challenges inherent in mastitis control. He noted that while >20 types of infections can cause mastitis, "at least 99% are caused by…*Str. agalactiae*, other streptococci, staphylococci and bacillary mastitis (including coliform, pseudomonas etc.)." He identified clinical, nonclinical, and severe states and noted that even though discrimination among pathogens could only be performed by laboratory testing, the clinical and nonclinical states did not occur at the same frequency for all pathogens. Murphy (1956) further stated that shedding (and the chance of negative cultures) varied among pathogens over time and emphasized the need for pathogen-specific control programs so that appropriate treatment could be applied to cows affected with *Strep. agalactiae* while calling for research to identify environmental sources of exposure for other pathogens.

Environmental Pathogens

Until the late 1970s, little emphasis was placed on gram-negative organisms as a cause of mastitis. Eberhart (1977) directed initial attention to the emergence of coliforms as mastitis pathogens and in 1979 a paper titled "Coliform mastitis—A review" was published in JDS by the Coliform Subcommittee of the Research