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Identification of factors influencing teat dip efficacy trial results by meta-analysis

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ABSTRACT

Two meta-analyses were conducted using data from peer-reviewed natural exposure (NE) and experimental challenge (EC) teat dip efficacy trials to identify factors influencing the new intramammary infection (IMI) rate. A NE data set containing 16 studies and an EC data set containing 21 studies were created. New IMI rate was calculated based on the percentage of new quarter infections per month (PNQI/mo) for each observation, in both data sets, and used as the dependent variable for model derivation. A linear, mixed-effects model with a random study effect, weighted by number of quarters eligible for infection, was derived for each data set. The final NE model included the effects of experimental design (split herd or split udder), mastitis pathogen group (*Staphylococcus aureus*, *Streptococcus agalactiae*, environmental streptococci, gram-negative species, *Corynebacterium* spp., or coagulase-negative staphylococci), postmilking treatment (iodine, chlorhexidine, linear dodecyl benzene sulfonic acid, chlorine compounds, phenol compounds, or undipped negative controls), and the interaction between mastitis pathogen group and postmilking treatment. Overall, *Corynebacterium* spp. had the highest new IMI rate (0.0139 ± 0.0018 PNQI/mo), and environmental streptococci and gram-negative species had the lowest (0.0023 ± 0.0022 PNQI/mo). Additionally, trials utilizing a split herd experimental design had a 2-fold higher new IMI rate than trials using a split udder design. The final EC model included the effects of mastitis pathogen (*Staph. aureus* and *Strep. agalactiae*), postmilking treatment (iodine, chlorine compounds, "other" active ingredients, or undipped negative controls), geographic region of study (Eastern, Southern, and Pacific Northwest), and the 2-way interactions of region and pathogen group and postmilking treatment and pathogen group. Overall, *Staph. aureus* and *Strep. agalactiae* had similar new IMI rates. Quarters dipped postmilking in either iodine (0.0127 ± 0.0099 PNQI/mo), chlorine compounds (0.0258 ± 0.0095 PNQI/mo), or "other" active ingredient teat dips (0.0263 ± 0.0106 PNQI/mo) had lower new IMI rates than undipped quarters (0.0859 ± 0.0087 PNQI/mo). These results indicate that experimental design influences the new IMI rate of teat dip efficacy trials and that using an effective postmilking teat dip has a greater effect on controlling the new *Staph. aureus* and *Strep. agalactiae* IMI rate than the teat dip's active ingredient.
Key words: natural exposure, experimental challenge, split udder, mastitis

INTRODUCTION

Teat disinfectants (teat dips) are important tools used to prevent mastitis in the modern dairy industry. Disinfection of teats before milking reduces the incidence of IMI caused by environmental mastitis pathogens (Pankey and Drechsler, 1993), and disinfection of teats after milking reduces the incidence of IMI caused by opportunistic and contagious mastitis pathogens (Pankey et al., 1984b; Quirk et al., 2012). The efficacy of a teat dip is determined not only by the active ingredient and its concentration, but by many additional factors. Consequently, testing all teat dips in a herd setting is important to confirm efficacy before commercial distribution. To date, many trials have been conducted to determine and confirm the efficacies of different teat dip formulations; however, a broad, quantitative synthesis of this body of literature has not yet been undertaken.

Quantitatively characterizing the factors that influence teat dip efficacy will allow for (1) more robust evaluation of teat dip–pathogen interactions; (2) evaluation of the importance of management variables such as utilizing pre- and postmilking teat dips and the corresponding active ingredient concentrations; and (3) quantitative understanding of differences among

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experimental approaches. Meta-analysis is a useful tool for summarizing previous literature that investigates the efficacy of different teat dips (St-Pierre, 2001; Sauvant et al., 2008). The objective of the present study was to use a meta-analysis approach to identify factors that significantly influenced the reported new IMI rates presented in peer-reviewed teat dip efficacy trials.

MATERIALS AND METHODS

Literature Search

Data from previously published, peer-reviewed studies that described efficacies of teat dips in reducing incidence of new IMI were obtained for this analysis. Inclusion and exclusion criteria established were a function of teat dip study design (natural exposure, **NE**, or experimental challenge, **EC**) and will be explained in subsequent sections.

In 1994, the National Mastitis Council (**NMC**) Research Committee began compiling a list of teat disinfectant studies published since 1980 that used either an NE or EC design to determine teat dip efficacy. In its last revision (NMC, 2014), this publication summarized 51 studies that were based on the following criteria: (1) only peer-reviewed publications were included; (2) only the information published within the study was summarized; (3) the study followed the NE or EC testing protocols; (4) studies reporting only nonsignificant results were not included, except NE studies using a positive control; and (5) publications must have included either the trade name or the manufacturer's information for the tested teat disinfectant. For the present study, the NE and EC studies cited within the 2014 NMC report were further refined based on the selection criteria described in the following sections and used to construct a data set of similar study designs.

Inclusion and Exclusion Criteria and Variables of Interest

The common inclusion and exclusion criteria applied to both NE and EC studies are described in this section, and the criteria specific to each study design (NE or EC) are outlined in the following sections. The NE and EC studies meeting the respective inclusion and exclusion criteria are presented in Tables 1 and 2. For inclusion in the respective data set, all studies must have only used products that were intended for commercial use. All studies included had either a split herd design in which all quarters of a single cow received the same treatment or a split udder design in which the right and left udder halves received different treatments. When a variable of interest was absent from the published manuscript, the corresponding author or the manufacturer was contacted to obtain this information.

Natural Exposure Studies

A total of 24 manuscripts utilizing an NE study design were identified from the NMC's teat disinfectant summary. Only studies using a teat disinfectant product of a single disinfectant class were included in the database, allowing for comparisons between different

Table 1. List of peer-reviewed reports contained in the natural exposure data set and corresponding study characteristics

Study	Study region[1]	Teat dips used	Control type[2]	Study design
Bray et al., 1983	Southern	Postmilking	Positive postmilking	Split herd
Drechsler et al., 1990	Eastern	Postmilking	Positive postmilking	Split udder and herd
Goldberg et al., 1994	Pacific Northwest	Pre- and postmilking	Positive postmilking	Split herd
Nickerson et al., 1986	Southern	Postmilking	Negative postmilking	Split herd
Oliver et al., 1989	Southern	Postmilking	Negative postmilking	Split udder
Oliver et al., 1990	Southern	Postmilking	Negative postmilking	Split udder
Oliver et al., 1991	Southern	Postmilking	Negative postmilking	Split udder and herd
Oliver et al., 1993a	Southern	Pre- and postmilking	Negative premilking	Split udder
Oliver et al., 1993b	Southern	Pre- and postmilking	Negative premilking	Split udder
Oliver et al., 1994	Southern	Pre- and postmilking	Negative premilking	Split udder
Oliver et al., 1999	Southern	Postmilking	Negative postmilking	Split udder
Oliver et al., 2001	Southern	Pre- and postmilking	Negative premilking	Split udder
Pankey et al., 1984a	Southern	Postmilking	Negative postmilking	Split herd
Pankey et al., 1985b	Southern	Postmilking	Negative postmilking	Split herd
Pankey et al., 1987	Eastern	Pre- and postmilking	Negative premilking	Split herd
Peters et al., 2000	Eastern	Pre- and postmilking	Positive premilking	Split herd

[1]Study locations were classified as either the Southern (Louisiana and Tennessee), Eastern (Vermont and Maryland), or the Pacific Northwest (Idaho) region of the United States.

[2]Negative control quarters were not treated with the dip specified and positive controls quarters were treated with an already demonstrated pre- or postmilking teat dip.