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Risk factors associated with bulk tank standard plate count, bulk tank coliform count, and the presence of *Staphylococcus aureus* on organic and conventional dairy farms in the United States

K. M. Cicconi-Hogan,*[1] M. Gamroth,† R. Richert,‡ P. L. Ruegg,‡ K. E. Stiglbauer,† and Y. H. Schukken*
*Department of Population Medicine and Diagnostic Sciences, Cornell College of Veterinary Medicine, Cornell University, Ithaca, NY 14853
†Department of Animal Sciences, Oregon State University, Corvallis 97331
‡Department of Dairy Science, University of Wisconsin-Madison, Madison 53706

ABSTRACT

The purpose of this study was to assess the association of bulk tank milk standard plate counts, bulk tank coliform counts (CC), and the presence of *Staphylococcus aureus* in bulk tank milk with various management and farm characteristics on organic and conventional dairy farms throughout New York, Wisconsin, and Oregon. Data from size-matched organic farms (n = 192), conventional nongrazing farms (n = 64), and conventional grazing farms (n = 36) were collected at a single visit for each farm. Of the 292 farms visited, 290 bulk tank milk samples were collected. Statistical models were created using data from all herds in the study, as well as exclusively for the organic subset of herds. Because of incomplete data, 267 of 290 herds were analyzed for total herd modeling, and 173 of 190 organic herds were analyzed for the organic herd modeling. Overall, more bulk tanks from organic farms had *Staph. aureus* cultured from them (62% of organic herds, 42% conventional nongrazing herds, and 43% of conventional grazing herds), whereas fewer organic herds had a high CC, defined as ≥50 cfu/mL, than conventional farms in the study. A high standard plate count (×1,000 cfu/mL) was associated with decreased body condition score of adult cows and decreased milk production in both models. Several variables were significant only in the model created using all herds or only in organic herds. The presence of *Staph. aureus* in the bulk tank milk was associated with fewer people treating mastitis, increased age of housing, and a higher percentage of cows with 3 or fewer teats in both the organic and total herd models. The *Staph. aureus* total herd model also showed a relationship with fewer first-lactation animals, higher hock scores, and less use of automatic takeoffs at milking. High bulk tank CC was related to feeding a total mixed ration and using natural service in nonlactating heifers in both models. Overall, attentive management and use of outside resources were useful with regard to CC on organic farms. In all models except the organic CC model, we observed an association with the average reported somatic cell count from 3 mo before the herd visit, indicating that many of the regularly tested milk quality parameters are interconnected. In conclusion, we found that conventional and organic farms are similar in regard to overall herd management, but each grazing system faces unique challenges when managing milk quality.
Key words: dairy, milk quality association, management, organic

INTRODUCTION

The rapid growth of the organic dairy industry has made research regarding organic milk quality and management practices essential. The resulting increase in certified organic dairy animals and production of organic dairy products is a consequence of a surge in consumer interest concerning animal welfare and the environmental impact of conventional dairy farming (Sundrum, 2001). The perception among consumers is that organically produced milk is healthier or of better quality (Yiridoe and Bonti-Ankomah, 2005), but previous research has found little difference regarding milk quality between organic and conventional farms (Rosati and Aumaitre, 2004; Sato et al., 2005).

Examining and monitoring bulk tank milk on a dairy farm is a useful and efficient method of assessing the quality of milk that the farm is producing. High levels of bacteria in raw milk can adversely affect the quality and shelf life of pasteurized milk (Schukken et al., 2003; Jayarao et al., 2006). Several tests are regularly used to assess the quality of bulk tank milk, such as SCC, SPC, laboratory pasteurized count, and coliform count (**CC**). Dairy processors use these tests to determine if their clients' products are high quality, and to evaluate whether milk is adequate for distribution and consumption.

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[1]Corresponding author: kmc277@cornell.edu

The SPC, also known as the plate loop count, assesses the bacterial density in the milk and estimates the number of aerobic bacteria present per milliliter of milk. Standard plate count is an excellent way to assess management and milk quality, as reported in previous research and milk quality management recommendations (van Schaik et al., 2002; Jayarao et al., 2004; Schroeder, 2009). A high bulk tank SPC can be the result of bacteria from unclean milking equipment, milk from cows with subclinical or clinical mastitis, or contamination from dirty udders (Murphy and Boor, 2000). The regulatory cut-off for SPC in the United States is 100,000 cfu/mL, which is also in accordance with the European Union standards.

Staphylococcus aureus is a contagious mastitis pathogen that can cause an IMI, which has a major effect on milk production and bulk tank SCC (Keefe, 2012). Because *Staph. aureus* IMI cause an increase in SCC at the cow level, *Staph. aureus* is positively associated with an increase in the bulk tank SCC. *Staphylococcus aureus* can spread easily from animal to animal in several ways—by milking units, though improper milking or handling, or lack of glove use, to name a few. Although methicillin-resistant *Staph. aureus* is one of the most well-known human pathogens, it does not appear to be a major issue in bulk tank milk in the United States [K. M. Cicconi-Hogan, N. Belomestnykh (Cornell University, Ithaca, NY), M. Gamroth, P. L. Ruegg, L. Tikovsky (Boehringer Ingelheim Vetmedica Inc., St. Joseph, MO), and Y. H. Schukken; personal communication; Haran et al., 2012]. Because of the potential effect that *Staph. aureus* has on milk quality and the significantly higher numbers of organic bulk tanks with *Staph. aureus* found in this study (Cicconi-Hogan et al., 2013), we felt that the presence of this organism was important to fully understand.

Coliform bacteria found in bulk tank milk, such as *Escherichia coli* and *Klebsiella* spp., are usually indicative of fecal contamination, often from soiled udders or teats (Hogan and Smith, 2003) and may occasionally be from a mastitis cow shedding high counts of these coliform bacteria. Although there is no regulatory limit on the amount of coliforms that can be present in raw milk, the Grade "A" Pasteurized Milk Ordinance (Food and Drug Administration, 2009) requires pasteurized milk to have a CC $\leq$10 cfu/mL. Other research has used $\leq$50 cfu/mL as the proposed cutoff for "good quality" in regard to coliforms in raw milk (Jayarao et al., 2004). When the SPC of a sample is below the regulatory limits, most coliforms will be removed from the milk by pasteurization before the milk is consumed. Occasionally, in the case of raw milk consumption or a pasteurization failure, coliforms in the milk can lead to severe human disease. Shiga toxin-producing *E. coli* O157:H7, which has been isolated from bulk tank milk (Karns et al., 2007), can cause severe hemorrhagic diarrhea in humans.

Previous analyses from our research determined that CC was lower on organic (**ORG**) farms and that *Staph. aureus* was higher on ORG farms compared with the conventional (**CON**) herds in our study (Cicconi-Hogan et al., 2013; Stiglbauer et al., 2013). Thus, CC and the presence of *Staph. aureus* were natural choices for further investigation. Although several studies have assessed bacterial milk quality and determined associations of bacterial counts with management factors, few have focused on the organic dairy population in the United States.

The objective of this study was to evaluate the relationship between management practices and bulk tank SPC, CC, and the presence of *Staph. aureus* for all herds involved in the study and specifically for the subset of organic herds. The aim was to identify management characteristics that are associated with good bacterial milk quality and that can be used to define best management practices for either conventional or organic dairy farms or both.

MATERIALS AND METHODS

Recruitment and Herd Selection

Our research team has collected longitudinal and cross-sectional data on 292 organic and frequency matched conventional dairy farms and reported on management characteristics (Stiglbauer et al., 2013), the use and role of veterinarians within these populations (Richert et al., 2013), and associations of management with SCC (Cicconi-Hogan et al., 2013); recruitment and herd inclusion criteria are described therein. Briefly, ORG herds selected for inclusion had a minimum of 20 adult cows and had been shipping organic milk for at least 2 yr. Included CON farms were within a 50-mile radius of an ORG farm and had a minimum of 20 adult cows. Dairy herds in New York (NY), Oregon (OR), and Wisconsin (WI) were visited between March 2009 and May 2011. A total of 192 ORG herds and 100 CON herds were frequency matched based on herd size and location. In New York, 72 ORG and 25 CON farms were visited; in Wisconsin, 96 ORG and 51 CON farms were visited; and in Oregon, 24 of both ORG and CON farms were visited.

Questionnaire and Data Collection

The study questionnaire was modified from previously published survey instruments (Zwald et al., 2004; Pol and Ruegg, 2007). It was reviewed by professional