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Invited review: Organic and conventionally produced milk—An evaluation of factors influencing milk composition

B. H. Schwendel,*[1] T. J. Wester,* P. C. H. Morel,* M. H. Tavendale,† C. Deadman,‡ N. M. Shadbolt,§ and D. E. Otter#
*Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Tennent Drive, Palmerston North 4474, New Zealand
†Animal Nutrition and Health, AgResearch Grasslands Research Centre, Tennent Drive, Palmerston North 4442, New Zealand
‡Fonterra Research Centre Palmerston North, Dairy Farm Road, Palmerston North 4442, New Zealand
§Institute of Agriculture and Environment, Massey University, Tennent Drive, Palmerston North 4474, New Zealand
#Food and Bio-based Products, AgResearch Grasslands Research Centre, Tennent Drive, Palmerston North 4442, New Zealand

ABSTRACT

Consumer perception of organic cow milk is associated with the assumption that organic milk differs from conventionally produced milk. The value associated with this difference justifies the premium retail price for organic milk. It includes the perceptions that organic dairy farming is kinder to the environment, animals, and people; that organic milk products are produced without the use of antibiotics, added hormones, synthetic chemicals, and genetic modification; and that they may have potential benefits for human health. Controlled studies investigating whether differences exist between organic and conventionally produced milk have so far been largely equivocal due principally to the complexity of the research question and the number of factors that can influence milk composition. A main complication is that farming practices and their effects differ depending on country, region, year, and season between and within organic and conventional systems. Factors influencing milk composition (e.g., diet, breed, and stage of lactation) have been studied individually, whereas interactions between multiple factors have been largely ignored. Studies that fail to consider that factors other than the farming system (organic vs. conventional) could have caused or contributed to the reported differences in milk composition make it impossible to determine whether a system-related difference exists between organic and conventional milk. Milk fatty acid composition has been a central research area when comparing organic and conventional milk largely because the milk fatty acid profile responds rapidly and is very sensitive to changes in diet. Consequently, the effect of farming practices (high input vs. low input) rather than farming system (organic vs. conventional) determines milk fatty acid profile, and similar results are seen between low-input organic and low-input conventional milks. This confounds our ability to develop an analytical method to distinguish organic from conventionally produced milk and provide product verification. Lack of research on interactions between several influential factors and differences in trial complexity and consistency between studies (e.g., sampling period, sample size, reporting of experimental conditions) complicate data interpretation and prevent us from making unequivocal conclusions. The first part of this review provides a detailed summary of individual factors known to influence milk composition. The second part presents an overview of studies that have compared organic and conventional milk and discusses their findings within the framework of the various factors presented in part one.
Key words: organic milk, milk composition, pasture, milk fatty acid

INTRODUCTION

Composition of bovine milk is influenced by many factors related either to the individual animal or to the animal's environment. Elements such as diet (Ferlay et al., 2008; Larsen et al., 2010), breed (Soyeurt et al., 2006; Palladino et al., 2010), individual animal genetics (Soyeurt et al., 2008), stage of lactation (Craninx et al., 2008; Stoop et al., 2009), management (Coppa et al., 2013), and season (Heck et al., 2009), as well as the interactions between them (Macdonald et al., 2008; Piccand et al., 2013; Stergiadis et al., 2013), affect milk composition, with many of the mechanisms behind these effects not fully understood. Therefore, when attempting to study the effect of one specific factor (e.g., diet) on cow milk composition, it is necessary to eliminate other influences. Those factors that cannot be eliminated must be accounted for and their effects considered and minimized.

Currently, there is no evidence that consumption of organic food leads to meaningful nutritional benefits

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[1]Corresponding author: heike.schwendel@agresearch.co.nz

for human health (Forman et al., 2012; Załecka et al., 2014). Studies purportedly comparing organic and conventionally produced milk are rife with complications. To be able to determine whether organic milk differs from conventionally produced milk, all factors that influence milk composition must be identical except for the factors that specifically define the farming system (organic or conventional). If more than the system factor varies between compared milk samples, it is difficult to determine whether results derive from the differences between the farming systems or are the consequence of other factors. Recent reviews (Magkos et al., 2003; Dangour et al., 2010; Guéguen and Pascal, 2010; Smith-Spangler et al., 2012) remarked on the lack of "true" comparison in studies evaluating organic and conventionally produced foods (including milk and dairy products). Many studies comparing organic and conventionally produced milk are inadequate in their discussion of the factors actually causing the results they present. Commonly, factors that could have contributed to the reported differences (between organic and conventional milk) have not been considered (e.g., differences in diet, breed, and animal health). Most studies proclaiming a comparison of organic and conventional milk used diets that varied in their amount of fresh forage and concentrate for organic and conventional cows, respectively. Consequently, the presented results are most likely related to the effect of the differences in diet, rather than to the fact that cows consumed organic or conventionally produced feed. On the contrary, studies that identify specific production differences for organic and conventional milk (e.g., higher amount of pasture in the diet of organic cows) fail to consider the influence of the farming system (organic or conventional) on their results (Palupi et al., 2012). Additionally, comparisons among studies are problematic because it is difficult to account for any number of variables, including sampling conditions (e.g., frequency of sampling, time of sampling, samples taken from individual cows vs. bulk milk vs. multiple farms), inherent differences in farming systems between regions, levels of input, and even regulatory differences in conventional and organic production between nations.

Regulations regarding organic dairy farming, although similar in principle, vary in detail (Table 1) between countries (e.g., pasture access and use of antibiotics). Therefore, heterogeneity of organic regulations may contribute to the variation in organic milk composition between countries.

The problems outlined above account for the inability of previous studies to reach a consensus on whether compositional differences exist between organic and conventionally produced dairy foods. Consequently, comparison of research studies should be undertaken with the awareness that study-specific factors can have a significant effect on animal production and milk composition and might have contributed to reported differences.

This review focuses on the chemical composition of bovine milk and summarizes the variety of different milk components that have been analyzed in regard to their quantitative and qualitative presence in organic and conventionally produced milk. It also aims to show how different milk components are influenced by a variety of individual factors and their interactions, and how the resulting variations can be perceived as differences between organic and conventional milks. It reinforces that these factors need to be considered when evaluating existing studies or designing comparative experiments. Variations within organic and conventional production methods have also created differences that have so far prevented development of a method to test the authenticity of organic milk products. A brief discussion of proposed tests to identify organically produced products is also included.

FACTORS THAT INFLUENCE MILK COMPOSITION

Numerous and varied factors influence milk yield and composition that, ideally, should be controlled when conducting a trial examining factors that may change milk composition. These factors can seem relatively minor, but they could account for a significant amount of variation. A study conducted by Roche et al. (2009) between 1995 and 2001 showed that the combined influence of weather, herbage quality, and herbage mineral concentration explained up to 22% of the variation in dairy cattle production. In a different trial, Roesch et al. (2005) compared cow performance from organic and integrated farming systems and found that milk yield positively correlated with breed (especially Holstein), concentrate feeding, routine teat dipping, and greater outdoor access during winter independent of the system. They concluded that lower milk yields (in organic and integrated cows) are a result of the individual animal and on-farm level factors such as breed, nutrition, management, and udder health. A study by Waiblinger et al. (2002), investigating 30 small, family-run dairy farms, suggested that milk production was lower on farms where management had negative attitudes toward interacting with cows during milking. Various factors that influence milk yield, as well as fat, protein, and lactose concentrations, at the farm and individual animal levels are compiled in Table 2.

The factors considered most influential, however, vary depending on study conditions and aims. Stage of lactation, for example, can be neglected when bulk milk samples are collected from a farm with an all-year-round calving system, but it becomes significant when