J. Dairy Sci. 99:1–9
http://dx.doi.org/10.3168/jds.2015-10140

Capitalizing on fine milk composition for breeding and management of dairy cows[1]

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ABSTRACT

The challenge of managing and breeding dairy cows is permanently adapting to changing production circumstances under socio-economic constraints. If managing and breeding address different timeframes of action, both need relevant phenotypes that allow for precise monitoring of the status of the cows, and their health, behavior, and well-being as well as their environmental impact and the quality of their products (i.e., milk and subsequently dairy products). Milk composition has been identified as an important source of information because it could reflect, at least partially, all these elements. Major conventional milk components such as fat, protein, urea, and lactose contents are routinely predicted by mid-infrared (MIR) spectrometry and have been widely used for these purposes. But, milk composition is much more complex and other nonconventional milk components, potentially predicted by MIR, might be informative. Such new milk-based phenotypes should be considered given that they are cheap, rapidly obtained, usable on a large scale, robust, and reliable. In a first approach, new phenotypes can be predicted from MIR spectra using techniques based on classical prediction equations. This method was used successfully for many novel traits (e.g., fatty acids, lactoferrin, minerals, milk technological properties, citrate) that can be then useful for management and breeding purposes. An innovation was to consider the longitudinal nature of the relationship between the trait of interest and the MIR spectra (e.g., to predict methane from MIR). By avoiding intermediate steps, prediction errors can be minimized when traits of interest (e.g., methane, energy balance, ketosis) are predicted directly from MIR spectra. In a second approach, research is ongoing to detect and exploit patterns in an innovative manner, by comparing observed with expected MIR spectra directly (e.g., pregnancy). All of these traits can then be used to define best practices, adjust feeding and health management, improve animal welfare, improve milk quality, and mitigate environmental impact. Under the condition that MIR data are available on a large scale, phenotypes for these traits will allow genetic and genomic evaluations. Introduction of novel traits into the breeding objectives will need additional research to clarify socio-economic weights and genetic correlations with other traits of interest.
Key words: dairy cattle, milk mid-infrared, management, breeding

INTRODUCTION

Management and breeding of dairy cows face the challenge of permanently adapting to changing production circumstances under socio-economic constraints. Previously, Olesen et al. (1999) linked sustainability not only to short- and long-term economic but also to environmental, genetic diversity, ethical, and social aspects. More recently, Boichard and Brochard (2012) also identified new challenges regarding sustainability with its 3 pillars: economic, societal, and environmental. They also supported the idea that relevant phenotypes will be needed to address already existing but also emerging challenges. Even if timeframes of action are different, challenges in management and breeding are similar and the requirement to access novel traits, especially linked to animal functionality, were clearly identified (e.g., Egger-Danner et al., 2015). Negative genetic trends in health and fitness traits have been observed in the last years because of their unfavorable genetic correlations with milk yield, the major trait of interest. To support the sustainability of dairy cattle production in the future, such unfavorable trends have to be compensated. Herd management, but also breeding, may have the potential to counterbalance for these effects to favor fertility, udder health, and metabolic diseases against increased production and therefore

Received July 20, 2015.
Accepted November 16, 2015.
[1]Presented as part of the Milk Spectral Data—Cost-effective information to improve expensive and limited traits in dairy cattle breeding Symposium at the ADSA-ASAS Joint Annual Meeting, Orlando, Florida, July 2015.
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these actions could increase profit without compromising welfare. Unfortunately, access to direct (i.e., cow heath) data is still a challenge, especially if large-scale and extensive comparable data across different herds are needed as, for instance, for breeding and benchmarking purposes. Similarly, management and selection for product quality (i.e., milk and subsequently dairy products) require access to high-throughput data given that alternative reference laboratory techniques (e.g., gas chromatography for fatty acid profiling) are out of question. Similarly opportunities to record direct behavioral and environmental impact traits are very limited, especially when we consider recording on a very large scale.

Standard milk components such as fat, protein, urea, and lactose contents, except SCC, are obtained using a technology called mid-infrared (**MIR**) spectroscopy (e.g., Biggs, 1978). Because the quantification of components is done using chemometric methods, the word spectrometry is also commonly used. As reported recently by De Marchi et al. (2014), this technology, which is installed in almost every milk analyses laboratory around the world, could also be used to determine fine milk composition. But this is not the final stage of development of this technology, as several innovations were recently described allowing its rise above an alternative method to detect chemical composition. The goal of this paper, inside the general symposium "Milk spectral data—Cost-effective information to improve expensive and limited traits in dairy cattle breeding," is to describe the latest developments and state of the art on the way that dairy cow management and breeding can benefit from milk composition assessed through MIR spectral data. This includes recent methodological innovations and developments to improve the use of fine milk composition, assessed through MIR spectral technology. Interactions between these innovations and the use of milk composition for breeding and management of dairy cows are described. Finally, recent innovations in the direct use of milk MIR spectral data are described.

USEFULNESS OF (FINE) MILK COMPOSITION

Not only is milk composition affected by the genetic background of cows (e.g., breed), but also the diet they are fed, their health, and numerous other effects. Changes in milk composition can also be used for precise monitoring of the status and health of the cows, and therefore their wellbeing, their diet, their environmental impact, and obviously the composition and the quality of their products (i.e., milk and subsequently dairy products). Milk composition traits play the role of indicator traits replacing a difficult to observe trait by a different, but reasonably highly correlated trait. An example is SCC, which was developed as an indicator of udder health (e.g., Schukken et al., 2003). The concept of a biomarker is defined as "a characteristic that is objectively measured and evaluated as an indicator of normal biologic processes, pathogenic processes, or . . . responses to an . . . intervention" (e.g., National Institutes of Health, 2001). The extension of the concept of biomarkers to different milk components, which then play the role of milk biomarkers, has been rather well described in literature (e.g., Bjerre-Harpøth et al., 2012).

Assessing Animal Health and Status

Due to the very intensive interaction between blood circulation and milk production (Bramley et al., 1992), milk composition is well recognized as a very easily accessible source of information on the (subclinical) changes in the health status of dairy cows (e.g., Hamann and Krömker, 1997). Mulligan et al. (2006) summarized that several milk components could be used in the detection of metabolic disorders (e.g., induced by an unbalanced diet). Major conventional milk components that have been available for a long time, such as fat, protein, and potentially urea and lactose, were considered by many researchers as potential tools and proxies to assess the changes in the status of the cows. Several examples were reported in literature. Plaizier et al. (2008) linked milk fat depression to potential SARA. Also, a high fat to protein ratio was suggested as an indicator for cows with a high risk of negative energy balance leading to related afflictions such as ketosis, displaced abomasum, ovarian cyst, lameness, mastitis, and body condition loss (Friggens et al., 2007). Frank and Swensson (2002) suggested that urea content, together with the protein content of the milk, could indicate the balance between protein and energy in the rumen. They also established that the efficiency of nitrogen utilization and the ammonia emission reduction could be optimized using the knowledge of urea and protein content. Brandt et al. (2010) summarized literature on the expected effects of mastitis on milk composition, including lactose. In a review, Arnould et al. (2013) summarized several scientific publications showing the benefit and the potential use of these traditional component, but also the use of novel milk composition traits such as fatty acids, BHB, lactoferrin, and others. Examples are the use of BHB in milk as a potential indicator of ketosis (Jorritsma et al., 1998) and lactoferrin (Kawai et al., 1999) as an indicator of mastitis. As reported by De Marchi et al. (2014) in their review, several studies associated body energy status, ketosis, and milk composition. Some authors stressed that cows with severe postpartum negative