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Assessing the effect of pregnancy stage on milk composition of dairy cows using mid-infrared spectra

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ABSTRACT

Changes in milk production traits (i.e., milk yield, fat, and protein contents) with the pregnancy stage are well documented. To our knowledge, the effect of pregnancy on the detailed milk composition has not been studied so far. The mid-infrared (MIR) spectrum reflects the detailed composition of a milk sample and is obtained by a nonexhaustive and widely used method for milk analysis. Therefore, this study aimed to investigate the effect of pregnancy on milk MIR spectrum in addition to milk production traits (milk yield, fat, and protein contents). A model including regression on the number of days pregnant was applied on milk production traits (milk yield, fat, and protein contents) and on 212 spectral points from the MIR spectra of 9,757 primiparous Holstein cows from Walloon herds. Effects of pregnancy stage were expressed on a relative scale (effect divided by the squared root of the phenotypic variance); this allowed comparisons between effects on milk traits and on 212 spectral points. Effect of pregnancy stage on production traits were in line with previous studies indicating that the model accounted well for the pregnancy effect. Trends of the relative effect of the pregnancy stage on the 212 spectral points were consistent with known and observed effect on milk traits. The highest effect of the pregnancy was observed in the MIR spectral region from 968 to 1,577 cm^{-1}. For some specific wavenumbers, the effect was higher than for fat and protein contents in the beginning of the pregnancy (from 30 to 90 or 120 d pregnant). In conclusion, the effect of early pregnancy can be observed in the detailed milk composition through the analysis of the MIR spectrum of bovine milk. Further analyses are warranted to explore deeply the use of MIR spectra of bovine milk for breeding and management of dairy cow pregnancy.
Key words: dairy cow, pregnancy, milk mid-infrared spectrum

INTRODUCTION

Pregnancy is an essential requirement for a dairy cow to start and to maintain her productive life. But pregnancy puts also an internal stress on the producing animal, as it needs to partition energy between different physiological functions. Therefore, the status of being pregnant is known to influence milk yield and major milk components (e.g., lactose, fat, and protein). Different studies have quantified the effect of pregnancy on milk, fat, and protein yields and contents (Olori et al., 1997; Loker et al., 2009; Penasa et al., 2016). Olori et al. (1997) reported a depression in milk, fat, and protein yields from the first month of pregnancy, with a significant decrease from the fifth month of pregnancy assuming a constant effect of the lactation stage. In the same way, Olori et al. (1997) reported that fat, protein, lactose, and solids contents at the eighth month of gestation were higher by 2.6, 0.2, 0.1, and 2.9 g/kg, respectively, for nonpregnant cows. Loker et al. (2009) reported a decrease in yields from the start of the pregnancy for Canadian Ayrshire, Jersey, Brown Swiss, and Guernsey dairy cows. More specifically, the significant decrease of milk and fat yields began in the fourth month of pregnancy, and the significant decrease of protein yield began in the second month of pregnancy. For Ayrshire dairy cows, the loss in milk, fat, and protein yields estimated by Loker et al. (2009) was of 3.7, 3.2, and 6.6%, respectively, at the fifth month of pregnancy. Recently, Penasa et al. (2016) investigated

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the effect of pregnancy stage on milk coagulation properties and showed a continuous improvement of these properties from the beginning to the end of pregnancy. They argued that this is probably due to the higher percentage of solids components in milk observed at that stage of pregnancy. Finally, Bohmanova et al. (2009) have shown that introducing the pregnancy status in genetic evaluation will considerably improve the goodness of fit of the models and, therefore, give more accurate breeding values. All these results confirmed that milk composition is influenced by the pregnancy status of dairy cows (pregnant versus nonpregnant) and varies according to the stage of pregnancy. However, to our knowledge, on a larger scale, only the pregnancy effect on major milk components has been investigated. Changes in minor milk components due to pregnancy can also be expected; in particular, progesterone profiles in milk have been reported to be different between a pregnant and a nonpregnant cow due to pregnancy and related endocrine changes (Friggens and Chagunda, 2005). Pregnancy-associated glycoproteins are a group of proteins specific to pregnancy that are synthesized and secreted by the placental tissue and are present in blood and in milk (Gajewski et al., 2008). On a larger scale, pregnancy effects on the whole detailed milk composition, meaning on major and on minor milk components, must still be investigated.

Milk laboratories provide a wide range of analyses, and results are routinely used by organizations advising dairy farmers in their management choices. The same results are often also used as phenotypes for the evaluation of the genetic potential of the animals. Fourier transform mid-infrared (**FT-MIR**) spectroscopy is the worldwide method of choice for the analysis of milk; FT-MIR allows high-throughput, low-cost, and large-scale analysis of milk that can provide qualitative and quantitative information on milk composition. Therefore, within official milk-recording schemes, most countries use FT-MIR to predict the major milk components (i.e., fat, protein, lactose, and urea contents; De Marchi et al., 2014). In recent years, intensive research has used FT-MIR also in the prediction of other, more minor, milk components, such as fatty acid (**FA**) profile (Soyeurt et al., 2006; Rutten et al., 2009, Soyeurt et al., 2011), protein composition (Bonfatti et al., 2011), and mineral content (Soyeurt et al., 2009) in relation with milk coagulation properties (Toffanin et al., 2015), and also other milk composition-related phenotypes, such as body energy status (McParland et al., 2011; McParland and Berry, 2016), ketone bodies (van Knegsel et al., 2010; Grelet et al., 2016) and hyperketonomia status (van der Drift et al., 2012), or methane emissions (Vanlierde et al., 2015). Along with this nonexhaustive list of milk components or phenotypes that can be predicted by FT-MIR, this method is also recognized as a convenient approach to convert spectral data (Gengler et al., 2016) into information on milk quality (e.g., FA composition and milk coagulation properties), cow health, or other traits of interest in management and breeding (De Marchi et al., 2014). Therefore, it is consensus that the main components of milk as well as detailed milk composition can be assessed through the mid-infrared (**MIR**) spectra obtained from the FT-MIR analysis of milk.

Usually, MIR spectra are used to predict a specific milk component (i.e., FA, minerals, or ketone bodies) by using the spectral data as predictors and the reference value of the components to be predicted as the response variable (Soyeurt et al., 2006; Grelet et al., 2015). Other innovative ways to use spectral data exist. As shown by several authors (e.g., Soyeurt et al., 2010; Dagnachew et al., 2013; Wang et al., 2016), MIR spectral data points (wavenumbers) can be considered traits reflecting detailed milk composition and can then be analyzed by genetic models. Considerable phenotypic and genetic variation in these traits has been shown; therefore, the next step is to study the origin of the observed phenotypic variation in these traits.

The aim of our study was to investigate the effect of pregnancy status on the detailed milk composition of primiparous Holstein cows assessed through the MIR spectra obtained from the routine FT-MIR analysis. The strategy we followed was therefore to consider MIR spectra as response variables to a given internal stress, the status of being pregnant. The effect of pregnancy on MIR spectra was compared with its known effect on milk yield, fat, and protein contents through all stages of pregnancy. This research could provide elements that will permit to adapt current genetics models by introducing the effect of the pregnancy stage, which may lead to new approaches for determining the pregnancy status of dairy cows directly from routine milk analysis. However, this may only be possible if the effect of the pregnancy status is known on predictors expected to be used to determine the pregnancy status of dairy cows; thus, the MIR spectra was the aim of our study.

MATERIALS AND METHODS

Data

Data used was collected between January 2012 and November 2014 by the milk-recording organization of the Walloon Region of Belgium, the Walloon Breeding Association (Ciney, Belgium). A total of 56,902 test-day (**TD**) records from the first lactation of 9,757 Holsteins and Red-Holsteins cows within 156 Walloon herds were selected. Those herds were enrolled in specific programs