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Characterization of the nongenetic causes of variation in the calcium content of bovine milk on French farms

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ABSTRACT

Milk is an important source of Ca in western diets. Milk Ca is important for the cheesemaking process and could be a useful biomarker of Ca regulation in cows. The objective of this study was to identify and quantify nongenetic factors affecting the variation of Ca content in bovine milk. During the PhénoFinLait program, a survey was performed in 3 major areas of milk production in France. This survey consisted of collecting milk samples, together with information about herd management and cow nutrition, from 924 commercial farms. More than 200,000 individual milk samples were collected, and Ca content was measured by mid-infrared spectroscopy. Each farm was surveyed several times during the year, and 3 to 6 milk samples were collected from each cow. An equation to predict milk Ca content from mid-infrared spectra was developed based on the Ca contents of 292 milk samples, and the milk Ca contents of the 200,000 samples were then predicted. Milk Ca content was lowest in Holstein cows, intermediate in Montbéliarde cows, and highest in Normande cows. For all 3 breeds, milk Ca decreased during the first month of lactation and increased after the fourth month of lactation, with the range between minimum and maximum values largest in Holsteins, intermediate in Montbéliardes, and smallest in Normandes. Milk Ca content also decreased with parity in all 3 breeds. By using multiple factorial analysis, 6 major feeding strategies employed on French dairy farms were characterized based on the data from the survey. Calendar month and cow feeding strategy affected milk Ca content, which dropped in the spring during grazing turnout and was lower when cows were fed fresh and conserved grass rather than corn silage. In conclusion, environmental factors induce variations in milk Ca content in addition to the genetics of the cows, which to date have been identified as a main factor of variation of milk Ca content in dairy cows. In several of the tested conditions, increases in milk production and in the amount of Ca daily secreted in milk were associated with a decrease in milk Ca content as though the mammary gland operated to limit the exportation of Ca when milk production rapidly increased. This result would suggest that milk Ca content could be a biomarker of Ca regulation in dairy cows.
Key words: dairy cow, calcium, milk

INTRODUCTION

Calcium is the major mineral contained in bovine milk, with a mean content of 1.25 g/kg (Alais, 1984). Bovine milk and dairy products are the main sources of Ca in the diets of many countries, especially western diets, and account for 75% of human Ca needs in the Netherlands (Flynn and Cashman, 1997). Milk Ca content is also an important determinant of milk coagulation and cheesemaking capability (Malacarne et al., 2014). However, large variations of milk Ca content exist around the cited average of 1.25 g/kg, with contents ranging between 0.9 and 1.4 g/kg (van Hulzen et al., 2009; Hurtaud et al., 2014; Poulsen et al., 2015; Chassaing et al., 2016). A better quantification and understanding of milk Ca content variation is necessary to evaluate the consequences of these variations on the amount of Ca contained in milk in human diets or on cheese production process. It would also allow exploration of the possibility of using milk Ca content as a biomarker of bone accretion and resorption in dairy cows.

Several studies showed that Ca secretion by mammary glands could be dependent on Ca regulation in mammals, and more specifically in cows (Horst et al., 1997; VanHouten et al., 2004). VanHouten et al. (2004) described in mice that a decrease in blood Ca, caused by decreasing diet Ca content, increased the expression and secretion of parathyroid hormone-related protein

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(**PTHrP**) and decreased the secretion of Ca into milk, resulting in a 50% decrease in milk Ca content. These effects were mediated by the Ca-sensing receptor of the mammary epithelial cell. This suggests a possibility that milk Ca could be a biomarker of some events involved in Ca regulation in cows, such as postpartum hypocalcemia or bone accretion and resorption dynamics during the lactation and gestation cycle. It is known that lactating cows undergo important cycles of bone resorption and accretion during lactation (Ekelund et al., 2006), but these cycles are difficult to quantify in large numbers of animals. The idea that milk Ca content could be a biomarker of these cycles would allow better understanding of, for instance, the consequences of mineral nutrition on those cycles or of cumulative unbalanced bone accretion and resorption during several lactations on cow longevity.

Variations in milk Ca content have been clearly related to the genetics of the cows, through systematic breed differences or high heritability within a breed (Hidiroglou and Proulx, 1982; van Hulzen et al., 2009; Buitenhuis et al., 2015; Toffanin et al., 2015b). The relationship between milk Ca content and cow diet, its evolution during the year, or its relationships with other effects, such as the stage of lactation or seasonality, have been less studied and have even been considered to be negligible compared with the relationship between milk Ca content and the genetics of the cows (Alais, 1984; Hermansen et al., 2005). Several studies showed an effect of lactation and seasonality on milk Ca content, but with contrasting results (Gaucheron, 2005; van Hulzen et al., 2009; Toffanin et al., 2015b; Chassaing et al., 2016). van Hulzen et al. (2009) described an increase in milk Ca content, of 0.578 mg/kg per day of lactation, throughout lactation, whereas Toffanin et al. (2015b) described a decrease of more than 100 mg/kg during d 5 to 35 and 36 to 65 of lactation, followed by a similar increase until the end of lactation. A possible reason for the discrepancies between these studies is the significant difficulty in dissociating the effects of the stage of lactation, the cows' diet, and the season.

The PhénoFinLait program (Gelé et al., 2014) consisted of surveying 945 farms between November 2009 and October 2010. The aim of our study was to use the samples and the data collected during this program to better quantify and characterize the nongenetic factors affecting variations of Ca content in bovine milk. Our assumption was that the high numbers of participating farms and the resulting diversity of milk production systems would allow for the dissociation and characterization of the effects of the stage of lactation, diet, and season to allow a better understanding of variations in Ca content in bovine milk.

MATERIALS AND METHODS

Study Design

The data used in our study were collected through the PhénoFinLait program, which consisted of a survey performed in the major areas of milk production in France (i.e., Alsace, Brittany, Franche-Comté, Normandy, and Pays de Loire). Between November 2009 and October 2010, 945 farms were surveyed. During this period, several visits (between 2 and 8, averaging 5) were performed at each farm to follow the evolution of the herd and cow diets over the course of a complete year. During each visit, interviewers collected data about the dairy cows (breed, parity, stage of lactation, stage of gestation, age of first calving, milk production) and their diet (description of the composition of the diets by using 54 variables). They also collected individual milk samples, and mid-infrared (**MIR**) spectra of the samples of each cow were measured in the laboratory. The survey resulted in 252,519 milk spectra, 9,180 frozen milk samples, 4,825 visits, and 63,818 dairy cows divided among the 3 main breeds in France (i.e., Holstein, Montbéliarde, and Normande) spread over 5 regions. The initial aim of the project was to characterize the effect of genomics and feeding on milk fatty acid and protein composition across the diversity of French dairy farms for 3 species (i.e., cattle, sheep, and goats; Sanchez et al., 2016). The PhénoFinLait program has been fully described by Gelé et al. (2014).

Prediction of Milk Calcium Content Using MIR Spectra

A prediction equation specific to our study was developed to predict milk Ca content from MIR spectra. To achieve this, the milk Ca contents of 292 frozen milk samples taken from the bank of samples of the PhénoFinLait program were analyzed by atomic absorption spectrometry after mineralization and dilution of the samples with nitric acid (AFNOR NF ISO 8070, 2007). Those samples were chosen to maximize the diversity of the potential factors affecting variations in Ca content (i.e., parity, lactation stage, breed, localization, cow diet, milk yield, and protein yield). The samples were split into 2 groups: the first group contained 205 samples for calibrating the prediction equation, whereas the second group contained 87 samples used as external data to validate the equation.

Characterization of Feeding Strategies

For each visit to each farm, the mean diet was estimated by averaging the proportions of each feed in the