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Short communication: Effects of pregnancy on milk yield, composition traits, and coagulation properties of Holstein cows

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ABSTRACT

The aim of this study was to investigate the effect of pregnancy stage on milk yield, composition traits, and milk coagulation properties in Italian Holstein cattle. The data set included 25,729 records from 3,995 first-parity cows calving between August 2010 and August 2013 in 167 herds. The traits analyzed were milk yield (kg/d), fat (%), protein (%), casein (%), and lactose (%) contents, pH, somatic cell score, rennet coagulation time (min), and curd firmness (mm). To better understand the effect of gestation on the aforementioned traits, each record was assigned to one of the following classes of pregnancy stage: (1) nonpregnant, (2) pregnant from 1 to 120 d, (3) pregnant from 121 to 210 d, and (4) pregnant from 211 to 310 d. Gestation stage significantly influenced all studied traits with the exception of somatic cell score. Milk production decreased and milk quality improved from the fourth month of pregnancy onward. For all traits, nonpregnant cows performed very similarly to cows in the first period of gestation. Rennet coagulation time and curd firmness were influenced by pregnancy stage, especially in the last weeks of gestation when milk had better coagulation characteristics; this information should be accounted for to adjust test-day records in genetic evaluation of milk coagulation properties.
Key words: Holstein cow, mid-infrared spectroscopy, milk coagulation property, pregnancy

Short Communication

The amount of milk used for cheese production worldwide is growing (Pieri, 2014). Therefore, it is important to evaluate some aspects of milk destined for the cheese industry, especially those related to technological quality. Several factors contribute to define milk quality and among them milk coagulation properties (**MCP**) are of particular interest because they affect the efficiency of the cheese-making process (Bynum and Olson, 1982; Pretto et al., 2013).

Traditionally, MCP have been recorded using mechanical systems that provide measures of milk clotting ability, the most common being rennet coagulation time (**RCT**, min) and curd firmness ($\mathbf{a_{30}}$, mm). The first trait defines the interval from the addition of rennet to milk to the start of gel formation, and the second measures the firmness of the coagulum 30 min after rennet addition (Annibaldi et al., 1977; McMahon and Brown, 1982). Besides mechanical devices, many other techniques are used to determine MCP (O'Callaghan et al., 2002); among them, mid-infrared spectroscopy is very popular in the dairy industry for rapid and cheap collection of milk phenotypes (De Marchi et al., 2014).

Pregnancy is responsible for a decline in milk yield (**MY**), particularly after mo 4 or 5 of gestation, when a significant amount of nutrients available in the blood of the cow is destined to the growth and maintenance of the developing fetus (e.g., Ragsdale et al., 1924; Olori et al., 1997; Leclerc et al., 2008). There is broad consensus that the physiological mechanisms by which gestation negatively affects MY in the last part of the lactation are mainly related to hormone-mediated partitioning of nutrients from milk production to pregnancy requirements (Oltenacu et al., 1980). Gestation stage also affects milk composition, particularly fat and protein percentages. Overall, these milk constituents increase as pregnancy advances, especially after the fourth month of gestation (Parkhie et al., 1966; Rodriguez et al., 1985; Olori et al., 1997). The effect of pregnancy on milk, fat, and protein yields has been widely investigated and is currently accounted for in the genetic evaluation of bulls and cows in different countries (including Italy) to adjust test-day milk production records (Interbull, 2015). Conversely, very few studies have dealt with the effect of gestation on milk constituents, and there is a lack of knowledge on the influence of gestation on MCP. Therefore, the aim of this work was to estimate the effects of pregnancy on test-day MY, composition traits (fat, protein, casein,

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and lactose percentages), pH, SCS, and MCP in first-lactation Holstein cows. The existence of a gestation effect on aforementioned traits would support the need to incorporate it in genetic evaluation models to avoid penalizing pregnant cows.

Records on daily milk yield, fat, protein, casein and lactose contents, pH, SCC, and coagulation properties (RCT and a_{30}) of first-parity Italian Holstein cows calving for the first time between 20 and 40 mo of age were provided by the Breeders Association of Veneto region (Padova, Italy). All herds were enrolled in official monthly test-day milk recording and cows were milked twice daily. Milk samples were analyzed in the laboratory of the Breeders Association of Veneto region using Milko-Scan FT6000 (Foss, Hillerød, Denmark). Milk coagulation properties were predicted using mid-infrared spectroscopy models developed by De Marchi et al. (2012, 2013).

Data were edited to remove cows without information on the subsequent calving date. Days in milk were restricted to be between 5 and 450, MY between 2 and 80 kg/d, fat content between 1.5 and 9%, protein content between 1 and 7%, casein content between 1 and 4%, lactose content >3.80%, SCC <10,000,000 cells/mL, pH between 6.40 and 6.85, RCT between 5 and 30 min and a_{30} <60 mm. For each test-date, values of SCC were log-transformed to SCS to achieve normality and homogeneity of variances according to the formula SCS = 3 + $\log_2$(SCC/100,000). Cows were retained if they produced all their records within the same herd and if they had at least 5 observations within the lactation. Contemporary groups were defined as cows sampled in the same herd-test-date (**HTD**), and HTD with fewer than 5 cows were removed from the data set.

Calving interval was computed as the number of days between the first and the second calving date, and days open (**DO**) were determined as follows: (1) if AI data were available, DO were calculated as the number of days between the last insemination (assumed as the insemination of success) and first calving date; (2) if AI data were not available, DO were estimated as calving interval minus an assumed gestation length (**GL**) of 280 d (Norman et al., 2009; Bastin et al., 2012). If AI data were available, GL was calculated by subtracting DO from calving interval, and only cows with GL between 210 and 310 d were retained. Days open <21 were deleted from the data set, and DO >365 were set to 365, as in Bastin et al. (2012). For each test-date record, days carried calf was calculated as DIM of the cow minus DO: if the difference was <0, the cow was identified as nonpregnant; otherwise, the cow was pregnant.

After editing, the final data set included 25,729 records of MY, composition traits, pH, SCS, and coagulation properties, and 3,995 calving interval and DO records from 3,995 first-parity cows calving between August 2010 and August 2013 in 167 herds. Based on days carried calf, as calculated as above, each record of MY, composition traits, pH, SCS, and MCP was assigned to one of the following classes of pregnancy stage, as in the approach of Parkhie et al. (1966): (1) nonpregnant (n = 8,742); (2) pregnant from 1 to 120 d (n = 10,111); (3) pregnant from 121 to 210 d (n = 5,959); and (4) pregnant from 211 to 310 d (n = 917). The average number of records per cow was 6.4 (range: 5 to 13) and the average number of cows sampled per herd in the period of the study was 24 (range: 5 to 200). Finally, the average number of cows sampled in the same HTD was 14 (range: 5 to 97).

Sources of variation of MY, composition traits, pH, SCS, and MCP were investigated using the following linear mixed model (SAS Institute Inc., Cary, NC):

$$y_{ijklm} = \mu + \mathrm{HTD}_i + \mathrm{AGE}_j + \mathrm{SL}_k + \mathrm{PS}_l + \mathrm{cow}_m + e_{ijklm},$$

where y_{ijklm} is the dependent variable (MY, fat, protein, casein, or lactose content, pH, SCS, RCT, or a_{30}); μ is the overall intercept of the model; HTD_i is the fixed effect of the ith herd-test-date ($i = 1$ to 1,788); AGE_j is the fixed effect of the jth class of age at calving of the cow ($j = 1$ to 12, with the first being a class from 20 to 22 mo, followed by 9 monthly classes, the second to last being a class from 32 to 33 mo, and the last being a class >33 mo); SL_k is the fixed effect of the kth class of stage of lactation of the cow ($k = 1$ to 12, with the first 10 being monthly classes, the second to last being a class from 306 to 350 d, and the last being a class >350 d); PS_l is the fixed effect of the lth class of pregnancy stage of the cow ($l = 1$ to 4, as previously described); cow_m is the random effect of the mth cow ($m = 1$ to 3,995) $\sim N\left(0, \sigma^2_{cow}\right)$; e_{ijklm} is the random residual $\sim N\left(0, \sigma^2_e\right)$. The distribution of records across classes of lactation and pregnancy stages is reported in Table 1.

Descriptive statistics of MY and fat and protein contents (Table 2) were very similar to national data reported by the Italian Breeders Association (AIA, 2013) for the first-parity Holstein population. Average MY was 25.4 kg/d for first-lactation Canadian Holsteins (Bohmanova et al., 2009), which is 3 kg less than the mean value of the present work. However, the study of Bohmanova et al. (2009) included test-day records from animals that calved from 1988 to 2006, and it is expected that cows from the initial period of the study produced significantly less milk than those of the last period. The mean value for a_{30} (Table 2) was 3.2, 4.1,