Effects of Ketosis Status Defined by FTIR Spectroscopy on Milk Quality Traits of First-lactation Cows

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Summary

The aim of the present study was to investigate the effect of ketosis status on milk yield and quality traits of Holstein Friesian cows. Individual milk samples (n = 15,674) of first-lactation cows from 5 to 60 days in milk (DIM) were collected during the official monthly test-day milk recording scheme and analysed for milk quality traits using Fourier transform infrared (FTIR) spectroscopy. Also, beta-hydroxybutyrate (BHB) was predicted by FTIR spectroscopy and used to classify records as normal, suspect or ketotic. Data were analysed with a linear mixed model including ketosis status, DIM and their interaction as fixed effects, and cow, herd-test-day and residual as random effects. Overall, ketotic cows exhibited the worst performance in terms of milk yield and quality compared to suspect and normal cows across the first 60 DIM. Results suggest that elevated milk BHB concentrations have a strong negative effect on milk yield and quality traits in early lactation.

Key words

dairy cow, ketosis, BHB, milk quality

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Introduction

Ketosis is a frequent metabolic disorder in dairy cattle and it occurs when cows are unable to manage the high energy request for milk production during the first days of lactation, inducing an abnormal concentration of circulating ketone bodies (hyperketonemia) (Herdt, 2000; Duffield et al., 2009). Ketosis negatively affects milk yield (Dohoo and Martin, 1984; Duffield et al., 2009; Ospina et al., 2010) and chemical composition (Duffield et al., 2009; Kayano and Kataoka, 2015; Santschi et al., 2016), and it impairs reproduction performance and health (Raboisson et al., 2014). Therefore, ketosis causes a relevant economic loss for the farmer, with an estimated average total cost per case of 265€ (McArt et al., 2015).

Although ketosis can manifest clinically, dairy cows often suffer from subclinical ketosis, defined as an excess of circulating ketone bodies in absence of clinical signs (Andersson, 1988). As a result, an early and accurate detection of this common disease is related to the measurement of ketones concentration in body fluids of dairy cows. The reference method for ketosis diagnosis is blood BHB concentration (Oetzel, 2004), as it is the predominant and stable circulating ketone body in ruminants. However, milk sampling and analysis represents a more practical tool for herd monitoring through the detection of elevated BHB concentrations in milk (Oetzel, 2004; Denis-Robichaud et al., 2014). Beta-hydroxybutyrate in milk can be predicted by Fourier transform infrared (FTIR) spectroscopy (de Roos et al., 2007; van Knegsel et al., 2010), which is a fast and cost-effective methodology already used in milk official recording system (De Marchi et al., 2014; Gottardo et al., 2015; Visentin et al., 2016). Recently, the potential of FTIR spectroscopy for screening hyperketonemia at the herd level has been demonstrated (Koeck et al., 2014; Santschi et al., 2016; Tatone et al., 2017).

The present study aimed to investigate the effects of ketosis status on milk yield and quality traits of Holstein Friesian cows.

Materials and methods

Individual milk samples from first-lactation Holstein Friesian cows reared in Veneto region (northeast Italy) were collected between May 2015 and November 2016 by the Breeders Association of Veneto region (ARAV, Padova, Italy), during the official monthly test-day milk recording scheme. Milk samples were analysed using Milko-Scan FT6000 (Foss Electric A/S, Hillerød, Denmark) for fat, protein, casein and lactose percentage. Milk BHB concentration was predicted by the same instrument using prediction models developed by Foss (Foss Electric A/S), as described by Koeck et al. (2014). Somatic cell count (SCC) was obtained by Fossomatic (Foss Electric A/S,) and subsequently transformed to somatic cell score (SCS) through the formula $SCS = 3 + \log_2(SCC/100{,}000)$.

Normal distribution was checked for each studied trait and records that deviate more than 3.5 standard deviations (SD) from the respective mean were discarded from the database. Only first-lactation cows with at least 2 tests between 5 and 60 days in milk (DIM) were considered and herd-test-day (HTD) with less than 3 cows were removed from the original dataset. After editing, the dataset included 15,674 milk samples from 7,835 first-lactation cows in 546 herds. Records were grouped in 3 classes according to the level of milk BHB: NORMAL, if milk BHB concentration was <0.15 mmol/L; SUSPECT, if milk BHB was between 0.15 and 0.19 mmol/L; and KETOTIC if milk BHB was ≥0.20 mmol/L (Koeck et al., 2014; Santschi et al., 2016).

Data were analysed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC, USA) according to the following linear model:

$$y_{ijklm} = \mu + DIM_i + K_j + (DIM \times K)_{ij} + cow_k + HTD_l + \varepsilon_{ijklm},$$

where y_{ijklm} is the dependent variable (daily milk yield, fat, protein, casein, lactose, SCS); μ is the overall intercept of the model; DIM_i is the fixed effect of the ith class of the stage of lactation (i = 1 - 8, the first five being classes of 5 d each, followed by classes of 10 d each); K_j is the fixed effect of the jth class of ketosis status (j = NORMAL, SUSPECT, KETOTIC); $(DIM \times K)_{ij}$ is the fixed interaction effect between DIM and ketosis status; cow_k is the random effect of the kth cow (k = 1 – 7,835) ~$N(0, \sigma^2_{cow})$; HTD_l is the random effect of the lth herd-test-day (l = 1 – 2,618) ~$N(0, \sigma^2_{HTD})$; and ε_{ijklm} is the random residual ~$N(0, \sigma^2_e)$. Multiple comparison of least squares means (LSM) was performed for the effect of ketosis status with the Bonferroni's adjustment (P < 0.05).

Results and discussion

Descriptive statistics and significance of fixed effects included in the statistical analysis of milk yield and quality traits are presented in Table 1. Milk yield, fat content and SCS averaged 30.08 kg/d, 3.87% and 2.57, exhibiting the highest coefficients of variation of 23.5%, 21.8% and 68.5%, respectively. Means of protein, casein and lactose content were 3.13%, 2.43% and 4.93%, respectively. Milk yield and chemical composition are consistent with official data published in 2016 by Italian Holstein Friesian Cattle Breeders Association (ANAFI, 2016). Overall, stage of lactation was the most relevant effect (P <0.001) in explaining the variability of studied traits, followed by ketosis status (P <0.001). On the other hand, ketosis status represented the most important source of variation for fat content. The first order interaction between ketosis status and stage of lactation significantly affected all the studied traits, except for SCS.

Least squares means of the studied traits among different BHB classes are shown in Table 2. Of the total 15,674 cow milk samples, 1,752 (11.2%) had BHB levels ≥0.15 mmol/L, suggesting a suspect or ketotic status of the cow. The threshold used in the present study corresponded to that reported by Tatone et al. (2017), as it was the lowest value associated with decreased milk production. As expected, milk yield was greatest for NORMAL cows. Difference between KETOTIC and NORMAL classes was 3.1 kg/d. This difference is slightly greater respect to milk losses reported for all parities (Dohoo and Martin, 1984; Duffield et al., 2009) or primiparous cows (Santschi et al., 2016), ranging from 1.0 to 2.1 kg/d. On the contrary, fat percentage was lowest for NORMAL (3.79%) cows and, following the increase of milk BHB concentrations, it increased for KETOTIC cows (4.69%). This result can be explained by greater fat mobilization occurring with hyperketonemia and it agrees with findings of other studies (Duffield et al., 2009; Santschi et al., 2016). On average, cows in KETOTIC class exhibited lower protein, casein and

Table 1. Mean and standard deviation (SD), *F*-value and significance of fixed effects in the analysis of milk yield and quality traits.

Trait[1]	Mean ± SD	Effect[2] DIM	Ketosis status	DIM* Ketosis status
Milk (kg/d)	30.08 ± 7.06	86.18***	36.13***	2.95***
Fat (%)	3.87 ± 0.85	94.61***	193.29***	3.48***
Protein (%)	3.13 ± 0.34	497.03***	10.36***	3.55***
Casein (%)	2.43 ± 0.26	348.31***	26.83***	3.11***
Lactose (%)	4.93 ± 0.21	233.48***	89.77***	1.91*
SCS	2.57 ± 1.76	23.68***	8.03***	0.67

[1] SCS = somatic cell score; [2] DIM = days in milk; Statistical significance is given as: ***P <0.001, **P <0.01, *P <0.05.

Table 2. Least squares means of milk yield and quality traits for ketosis status according to milk BHB concentration

Trait[1]	Normal (BHB <0.15 mmol/L)	Suspect (BHB 0.15-0.19 mmol/L)	Ketotic (BHB ≥0.20 mmol/L)
Milk (kg/d)	29.94[a]	29.26[b]	26.81[c]
Fat (%)	3.79[c]	4.12[b]	4.69[a]
Protein (%)	3.12[a]	3.08[b]	3.06[b]
Casein (%)	2.42[a]	2.38[b]	2.34[c]
Lactose (%)	4.95[a]	4.90[b]	4.80[c]
SCS	2.55[a]	2.65[a]	2.99[b]

[1]SCS = somatic cell score; [a-c] Least squares means with different letters across milk BHB concentrations are significantly different according to Bonferroni's test (P <0.05).

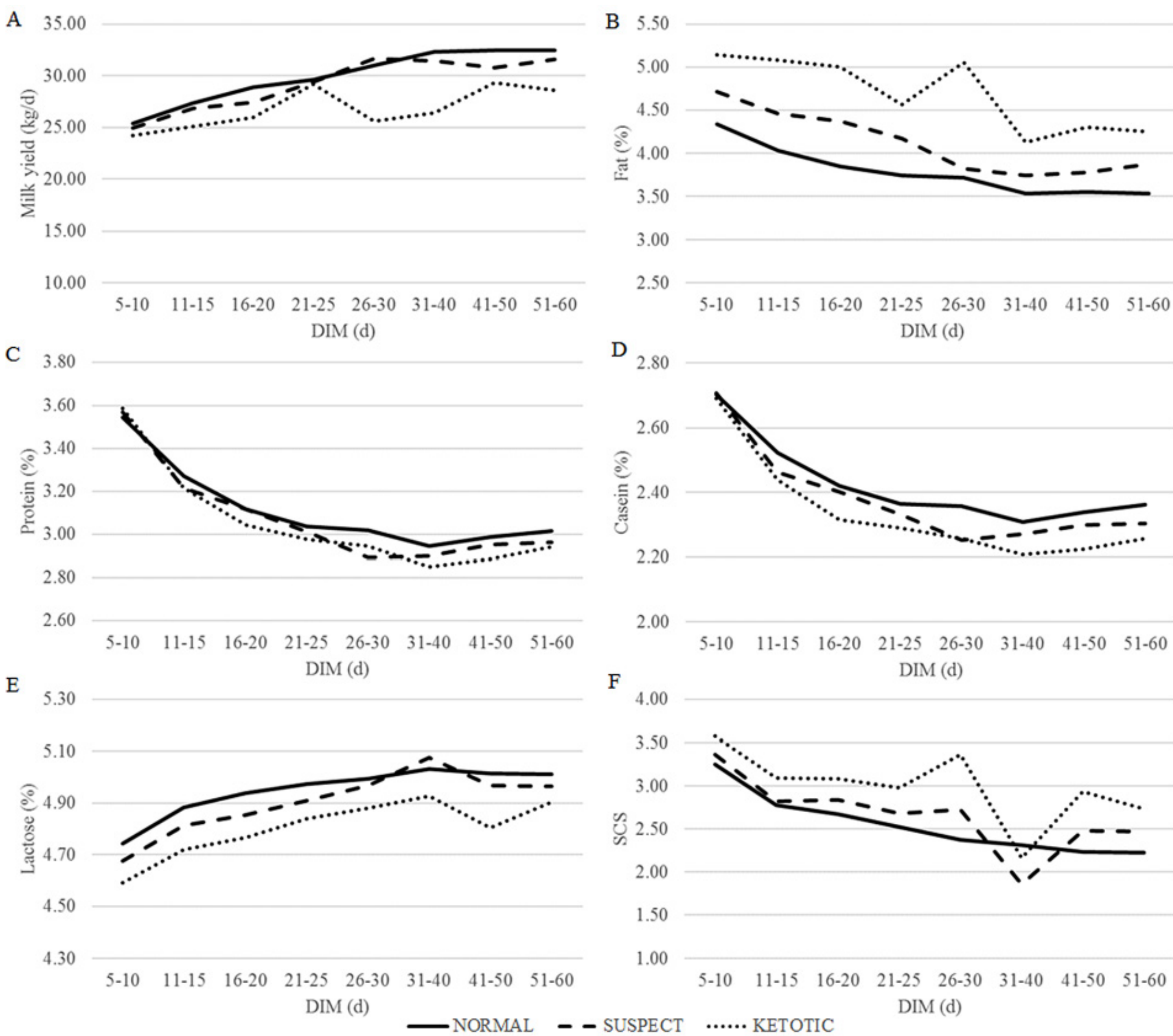

Figure 1. Least squares means of (A) milk yield, (B) fat content percentage, (C) protein content percentage, (D) casein content percentage, (E) lactose content percentage and (F) somatic cell score (SCS) according to ketosis status across days in milk (DIM).

lactose percentages than NORMAL animals. On the other hand, an opposite situation was observed for SCS, which was highest in KETOTIC class. Intermediate values were detected for SUSPECT class for all considered variables. Negative effects of hyperketonemia on chemical composition have been described by Duffield et al. (2009) and Santschi et al. (2016), who identified as possible reasons the decrease of microbial synthesis caused by negative energy balance, or poor feeding and lower dry matter intake associated with ketosis (Goldhawk et al., 2009; Kayano and Kataoka, 2015). Concerning increased SCS, Raboisson et al. (2014) reported odds ratios of 1.42 for doubling of SCC and 1.61 for clinical mastitis for cows affected by ketosis.

In general, milk yield and quality traits across DIM exhibited trends that were congruent with ketosis status (Figure 1). Similarly, Santschi et al. (2016) observed an increased difference of milk production between ketotic and normal cows during first weeks of lactation. Finally, despite the decreasing in ketosis prevalence, alterations of milk quality for KETOTIC class were observed during the whole period of the study.

Conclusions

Results from the present study clearly indicate that ketosis negatively affects milk yield and quality traits in early lactation. Primiparous cows exhibited significantly different performance across ketosis status classes. NORMAL class showed a more suitable milk and greater yield than KETOTIC class, whereas SUSPECT cows were in an intermediate position. Same trends of difference between classes were generally observed for all studied traits across DIM. Further researches should focus on entire lactation performance of all parity cows, in order to define a more comprehensive ketosis impact.

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