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Short Communication

Effect of THI on milk coagulation properties of Holstein-Friesian dairy cattle

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ABSTRACT - The objective of this study was to evaluate the effect of temperature-humidity index (THI) on the milk coagulation properties of Holstein-Friesian dairy cattle from northeast part of Italy. A total of 592 individual milk samples from six dairy herds were evaluated. The milk coagulation properties traits analysed were milk rennet coagulation time and curd firmness, as well as the fat, protein, and casein contents, pH, milk aptitude to coagulate (IAC), and the somatic cell count. The THI was determined during the periods of sample collection. The THI results showed that values of up to 75 did not significantly change the IAC values; however, when the THI values were above 75, the IAC decreased significantly. The control of THI can be used to guarantee appropriate milk coagulation properties.

Key Words: clotting, curd firmness, dairy cow, heat stress

Introduction

The milk coagulation properties (MCP) are an important characteristic of milk for cheese production (Summer et al., 2002; Cassandro et al., 2008). It is affected by various factors such as milk composition, breed, herd, year, and season. Several studies have investigated the relationship between MCP and milk quality traits both from the phenotypic and genetic points of view (Comin et al., 2008; Frederiksen et al., 2011; Toffanin et al., 2012; Tiezzi et al., 2015). In general, the main milk coagulation traits studied are the milk rennet coagulation time (RCT, min) and curd firmness (a_{30}, mm), but these two separate traits have been combined by Penasa et al. (2015) to give the aggregate index of milk aptitude to coagulate (IAC). The IAC was introduced as a new standardised trait to summarise RCT and a_{30}, both with the same importance (50%) in the index. The IAC could be adopted by the dairy industry as a global measure of MCP to reward or penalise milk for clotting characteristics in payment systems.

The milk composition can vary, since factors related to management, genetics, and the nutritional "status" can affect the basic milk constituents. The genetic changes influence the milk composition slowly, while changes related to the management and nutrition can provide changes faster (González, 2004). Heat stress, for example, negatively affects production and the milk composition of lactating dairy cows (Zimbelman et al., 2013). Fagan et al. (2010) evaluated the chemical composition of the milk from two herds with respect to the seasons and the best chemical composition and increased milk production were found in the winter and autumn. The temperature associated with moisture can have an even greater impact on these traits. In fact, the temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity, associated with the level of thermal stress (Armstrong, 1994; Bohmanova et al., 2007). This index is widely used in hot areas all over the world to assess the effect of heat stress on dairy cows (Bouraoui et al., 2002; Brown-Brandl et al., 2003). Indeed, the heat stress is related to decreased milk production and an altered composition (Schneider et al., 1988; West et al., 2003; Bohmanova et al., 2007, Gantner, 2011). The objective of this study was to evaluate the effect of THI on the coagulation properties of the milk of Holstein-Friesian dairy cattle located in the northeastern part of Italy.

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Material and Methods

We evaluated a total of 592 individual milk samples from Holstein-Friesian cows from six dairy herds located in the province of Venice (northeastern part of Italy), from July to November 2015. The samples were collected in the interval of two months, the first collection in the summer and the second collection in the fall. For only a farm, the collection interval was three months. The analyses were carried out in an official milk analysis laboratory with milk samples that were part of the milk recording system. The period between the collection and analysis were 36-72 h. All the samples arrived at the laboratory in refrigerated coolers with the addition of a preservative (Bronopol, Knoll Pharmaceuticals, Nottingham, UK) at a concentration of 250 μL 50 mL^{-1} milk.

The milk samples were analysed for their fat, protein and casein contents, and pH using a MilkoScan FT6000 (Foss Electric A/S) and for the somatic cell count (SCC) using a Fossomatic 5000 (Foss Electric A/S). The values for SCC were log-transformed to give the somatic cell score (SCS) to achieve normality and homogeneity of the variances according to the following formula:

$$SCS = 3 + \log_2 (SCC/100{,}000) \quad (1)$$

The RCT and a_{30} were predicted by MIRS using a Milko-Scan FT6000 (Foss Electric A/S) and the milk coagulation ability index (IAC) was calculated using the following formula according to Penasa et al. (2015):

$$IAC = 100 + [(a_{30} - mean_{a30})/SD_{a30} \times 2.5] - [(RCT - mean_{RCT})/SD_{RCT} \times 2.5] \quad (2)$$

To calculate the IAC, the mean and standard deviation of the experimental data were used.

The THI index was computed according to the following National Research Council formula (NRC, 1971):

$$THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T - 26), \quad (3)$$

in which T = temperature (°C) and RH = relative humidity (%).

The THI was calculated with the average values of environmental temperature and relative humidity. The average was obtained with the values of these parameters regarding the week of sampling. The data for the temperature and relative humidity were downloaded from the official web site (http://www.ilmeteo.it).

An ANOVA was applied to the IAC index data using the GLM procedure of SAS (Statistical Analysis System, version 9.3), according to the following linear model:

$$y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_l + \varepsilon_m + e_{ijklm},$$

in which y_{ijklm} is the dependent variable (IAC); μ the overall intercept of the model; α_i is fixed effect of the *i*-th herd of the cow sampled; class of β_j is the fixed effect of the *j*-th class of THI (j = <60; 60-65; 70-75; >75); γ_k is the fixed effect of the *k*-th class of fat content of milk; δ_l is the fixed effect of the *l*-th class of casein content of milk; ε_m is the fixed effect of the *m*-th class of somatic cells count content of milk; and e_{ijklm} is the random residual ~N (0, σ^2_e).

Results and Discussion

The averages for the fat, protein, and casein percentages, pH, and SCS were 3.75, 3.35, and 2.59 g/100 g, and scores of 6.56 and 3.57, respectively (Table 1). These results are in agreement with those of Cassandro et al. (2008) and De Marchi et al. (2008), although the value for SCS was slightly higher.

The average RCT value was 27.54 min, which is not close to the optimal value recommended for the renneting ability of milk (Zannoni and Annibaldi, 1981) or of the value of 16.69 min reported by Penasa et al. (2015) by MIRS. The average value for a_{30} was 17.83 mm, which is a low value for the milk renneting ability (Zannoni and Annibaldi, 1981).

The temperature-humidity index can be used to determine the influence of heat stress on the productivity of dairy cows (Gantner et al., 2011). Armstrong (1994) classifies heat stress according to the THI variation as

Table 1 - Descriptive statistics of milk composition and milk coagulation traits

Trait	N	Mean	SD (%)	Minimum	Maximum	Correlation with THI
Fat (g/100 g)	592	3.75	0.80	1.34	6.72	0.019
Protein (g/100 g)	592	3.35	0.44	2.3	5.12	–0.285[2]
Casein (g/100 g)	592	2.59	0.36	1.75	3.99	–0.314[2]
pH	592	6.56	0.07	6.30	6.79	–0.006
SCS[1]	592	3.57	2.35	–2.05	10.60	0.053
RCT (min)	592	27.54	6.67	8.62	56.95	0.262[2]
a_{30} (mm)	592	17.83	9.96	0.00	75.74	–0.293[2]
IAC	592	100.00	4.79	84.50	121.62	–0.290[2]
THI	592	67.59	10.50	54.04	81.53	

RCT - milk coagulation time; a_{30} - curd firmness; IAC - milk aptitude to coagulate index; THI - temperature-humidity index; SCS - somatic cell score; SD - standard deviation.
[1] SCS = [3 + $\log_2$ (SCC/100,000)].
[2] P<0.001.

mild (72-78), moderate (79-89), and severe (90-99) and a THI below 72 characterizes an environment without heat stress. According to this author, the milk production is affected by heat stress when the THI values are higher than 72 (Armstrong, 1994), but according to Bernabucci et al. (2010), who made an extensive evaluation using over one million Italian Holstein lactation records, their results indicated that milk yield losses began at an average THI value of 68. However, heat stress could also cause changes in the milk composition, somatic cell counts (SCC), and mastitis frequency (Rodriguez et al., 1985; Du Preez et al., 1990); thus, these changes could also compromise the milk coagulation properties and, consequently, the IAC.

During the period of this study, the THI values (Table 1) were between 81.53 in July (moderate heat stress) and 54.04 in November (characterizes an environment without heat stress). The THI values were grouped into four ranges: less than 60, between 60 and 65, between 70 and 75, and finally greater than 75. Only in July was the THI value above 72, considered highly critical (Figure 1).

The protein and casein contents were negatively associated with THI (–0.285, –0.314, respectively) (Table 1), the same observed by Bouraoui et al. (2002) for the milk protein percentage, which significantly decreased as a result of summer heat stress (2.96 vs. 2.88%), with THI values of 68 in the spring and 78 in the summer).

The RCT was positively correlated with THI and the correlation was negative for a_{30} and IAC (0.262, –0.293, and –0.290, respectively (P<0.001) (Table 1).

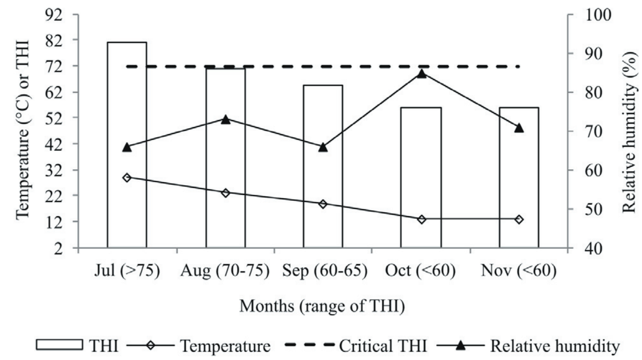
The effects of herd, THI, fat (%), casein (%), and CSC on IAC were significant in explaining the variability of the trait (P<0.05) (Table 2). It can be seen that when the THI values were below 75, there were no large changes in the IAC value, but when the THI values were above 75, the IAC decreased significantly (Figure 2).

The results indicated an effect of THI on IAC. Indices of THI between 72 and 78 were considered mild by Armstrong (1994), but it was observed in this study that values above 75 negatively contributed to IAC.

Table 2 - Analysis of variance for milk coagulation ability index expressed on scale 100±5 scores

Effect	df	F	P-value
Herd	5	49.15	<.0001
THI	3	48.54	<.0001
Fat (%)	1	115.80	<.0001
Casein (%)	1	45.18	<.0001
SCS	1	84.13	<.0001
R^2	0.52		
RMSE	3.34		

THI - temperature-humidity index; SCS - somatic cell score; R^2 - coefficient of determination; RMSE - root mean square error.



THI - temperature-humidity index.

Figure 1 - Average temperature, relative humidity, and THI variation.

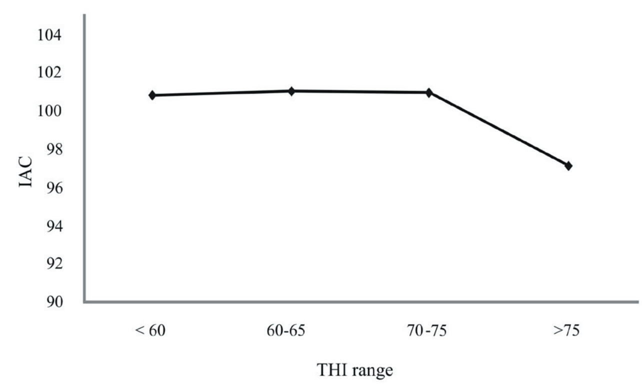


Figure 2 - Relationship between index of milk aptitude to coagulate (IAC) and temperature-humidity index (THI).

Conclusions

Temperature-humidity index values below 75 do not cause significant changes in values of the index of milk aptitude to coagulate, but when the values of temperature-humidity index are above 75, the decrease in index of milk aptitude to coagulate is relevant. The control of temperature-humidity index can be used to guarantee appropriate milk coagulation properties.

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References

Armstrong, D. V. 1994. Heat stress interaction with shade and cooling. Journal of Dairy Science 77:2044-2050.

Bernabucci, U.; Lacetera, N.; Baumgard, L. H.; Rhoads, R. P.; Ronchi, B. and Nardone, A. 2010. Metabolic and hormonal adaptations to heat stress in domesticated ruminants. Animal 4:1167-1183.

Bohmanova, J.; Misztal, I. and Cole, J. B. 2007. Temperature-humidity indices as indicators of milk production losses due to heat stress. Journal of Dairy Science 90:1947-1956.

Bouraoui, R.; Lahmar, M.; Majdoub, A.; Djemali, M. and Belyea, R. 2002. The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research 51:479-491.

Brown-Brandl, T. M.; Nienaber, J. A.; Eigenberg, R. A.; Freetly, H. C. and Hahn, G. L. 2003. Thermoregulatory responses of feeder cattle. Journal of Thermal Biology 28:149-157.

Cassandro, M.; Comin, A.; Ojala, M.; Dal Zotto, R.; De Marchi, M.; Gallo, L.; Carnier, P. and Bittante, G. 2008. Genetic parameters of milk coagulation properties and their relationships with milk yield and quality traits in Italian Holstein cows. Journal of Dairy Science 91:371-376.

Comin, A.; Cassandro, M.; Chessa, S.; Ojala, M.; Dal Zotto, R.; De Marchi, M.; Carnier, P.; Gallo, L.; Pagnacco, G. and Bittante, G. 2008. Effects of composite β- and κ-casein genotypes on milk coagulation, quality, and yield traits in Italian Holstein cows. Journal of Dairy Science 91:4022-4027.

De Marchi, M.; Bittante, G.; Dal Zotto, R.; Dalvit,C. and Cassandro, M. 2008. Effect of Holstein Friesian and Brown Swiss breeds on quality of milk and cheese. Journal of Dairy Science 91:4092-4102.

Du Preez, J. H.; Hatting, P. J.; Giesecke, W. H.; Eisenberg, B. E. 1990. Heat stress in dairy cattle and other livestock under Southern African conditions. III. Monthly temperature-humidity index mean values and their significance in the performance of dairy cattle. Onderstepoort Journal Veterinary Research 57:243-248.

Fagan, E. P.; Jobim, C. C.; Calixto Júnior, M.; Silva, M. S. and Santos, G. T. 2010. Fatores ambientais e de manejo sobre a composição química do leite em granjas leiteiras do Estado do Paraná, Brasil. Acta Scientiarum Animal Sciences 32:309-316.

Frederiksen, P. D.; Hammershøj, M.; Bakman, M.; Andersen, P. N.; Andersen, J. B.; Qvist, K. B. and Larsen, L. B. 2011. Variations in coagulation properties of cheese milk from three Danish dairy breeds as determined by a new free oscillation rheometry-based method. Dairy Science and Technology 91:309-321.

Gantner, V.; Mijić, P.; Kuterovac, K.; Solić, D. and Gantner, R. 2011. Temperature-humidity index values and their significance on the daily production of dairy cattle. Mljekarstvo 61:56-63.

González, D. H. F. 2004. Pode o leite refletir o metabolismo da vaca? p.195-197. In: O compromisso com a qualidade do leite no Brasil. Dürr, J. W., ed. UPF, Passo Fundo.

NRC - National Research Council. 1971. Committee on Animal Nutrition Agricultural Board. "Atlas of nutritional data on United States and Canadian feed." Natl. Acad. Sci., Washington, D.C.

Penasa, M.; De Marchi, M.; Ton, S.; Ancilotto, L and Cassandro, M. 2015. Reproducibility and repeatability of milk coagulation properties predicted by mid-infrared spectroscopy. International Dairy Journal 47:1-5.

Rodriguez, L. W.; Mekonnen, G.; Wilcox, C. J.; Martin, F. G. and Krienk, W. A. 1985. Effects of relative humidity, maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield. Journal of Dairy Science 68:973-978.

Schneider, P. L.; Beede, D. K. and Wilcox, C. J. 1988. Nycterohemeral patterns of acid-base status, mineral concentrations and digestive function of lactating cows in natural or chamber heat stress environments. Journal Animal Science 66:112-125.

Summer, A.; Malacarne, M.; Martuzzi, F. and Mariani, P. 2002. Structural and fuctional characteristics of Modenese cow milk in Parmigiano-Reggiano cheese production. Annali della Facoltà di Medicina Veterinaria Università di Parma 22:163-174.

Tiezzi, F.; Valente, B. D.; Cassandro, M. and Maltecca, C. 2015. Causal relationships between milk quality and coagulation properties in Italian Holstein-Friesian dairy cattle. Genetics Selection Evolution 45:47.

Toffanin, V.; De Marchi, M.; Penasa, M.; Pretto, D. and Cassandro, M. 2012. Characterization of milk coagulation ability in bulk milk samples. Acta Agriculturae Slovenica Supplement 3:93-98.

Zannoni, M. and Annibaldi, S. 1981. Standardization of the renneting ability of milk by Formagraph. Scienza e Tecnica Lattiero-Casearia 32:79-94.

Zimbelman, R. B.; Collier, R. J. and Bilby, T. R. 2013. Effects of utilizing rumen protected niacin on core body temperature as well as milk production and composition in lactating dairy cows during heat stress. Animal Feed Science and Technology 180:26-33.

West, J. W.; Mullinix, B. G. and Bernard, J. K. 2003. Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. Journal of Dairy Science 86:232-242.