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Direct and indirect genetic indices for milk coagulation properties in Italian Holstein Friesian sires

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ABSTRACT

Aim of this study was to define direct and indirect indices for milk coagulation properties (MCP) in Italian Holstein Friesian sires. A total of 315,700 individual milk samples from 49,183 cows were collected in 479 dairy farms from September 2011 to February 2014. Rennet coagulation time (RCT) and curd firmness (a_{30}) were predicted using mid-infrared spectroscopy. Sire breeding values (EBV) for RCT and a_{30} were estimated using a repeatability single-trait animal model, which included herd-test-day, days in milk, age at parities and season of parity as fixed effects, and cow permanent environment and animal as random effects. The direct genetic index for milk coagulation ability (IAC) was defined as the combination of EBV for RCT and a_{30} with equal weight, and then expressed on a scale with mean 100 and standard deviation of 5. A stepwise method was chosen to combine official EBVs for traits published by the Italian Holstein Friesian Cattle Breeders Association in a genetic index able to predict the direct IAC. Only sires with at least 10 daughters (scored for MCP) in 5 different herds were considered. The official EBVs retained by the regression analysis were those of protein and fat content, somatic cell score and the genetic variants for k-casein. Results of direct and indirect selection for MCP are presented.
(Keywords: genetic evaluation, milk coagulation properties, Holstein Friesian bulls)

INTRODUCTION

Despite cheese manufacture is the first destination of milk produced in Italy, the three major Italian dairy breeders associations (Holstein, Brown Swiss and Simmental) have not provided yet a direct genetic selection index to improve the milk aptitude to be transformed in cheese. Several studies have been published on cheese processing but they were performed only on a small number of animals, using bulk milk or with laborious procedures that can hardly be applied in routine (*Annibaldi et al.*, 1977*; Zannoni and Annibaldi*, 1981*; Aleandri et al.*, 1989; *Malacarne et al.*, 2006; *De Marchi et al.*, 2008). Recently, mid-infrared spectroscopy (MIRS) has been proposed as a cheap technology to predict milk coagulation properties (MCP) at population level (*De Marchi et al.*, 2009). The use of MIRS has made possible the storage of milk spectra and the development of prediction models for MCP (*Dal Zotto et al.*, 2008; *De Marchi et al.*, 2012; *De Marchi et al.*, 2014). Moreover, MCP have been found to have an exploitable additive genetic variation in dairy cattle populations, and estimated heritabilities from 15 to 41% (*Ikonen et al.*, 2004; *Cassandro et al.*, 2008; *Vallas et al.*, 2010). Therefore, the

improvement of MCP through genetic selection is feasible. Aim of this study was to define direct and indirect genetic indices for MCP in Italian Holstein Friesian sires.

MATERIAL AND METHODS

Phenotypic data

In the summer of 2011 the calibration curves for MCP were installed in Milko-scan FT6000 (*Foss Electric A/S*) of the Regional Breeders Association (Padova, Italy) for routine prediction of MCP as reported by *De Marchi et al.* (2012). Authors estimated satisfactory accuracies for the prediction equation of MCP, with coefficients of determination in cross-validation of 0.76 and 0.70 for RCT and a_{30}, respectively. Moreover, every 45 days a ring test is carried out by the 2 laboratories of the Regional Breeders Association to evaluate the effectiveness of MCP models and to reduce bias between FTMIR instruments and reference data (*De Marchi et al.*, 2012).

From September 2011 rennet coagulation time (RCT) and curd firmness (a_{30}) become available for cows reared in Veneto region and in April 2014 315,700 individual milk samples from 49,183 Holstein-Friesian cows collected in 479 dairy farms during monthly test-day milk recording were used for the estimation of breeding values for MCP.

Direct selection index

After discarding samples outside biological ranges and levels of fixed effects with low frequency, the Intermizoo SpA AI company (Padova, Italy) analyzed RCT and a_{30} with a repeatability single-trait animal model, which included herd-test-day, days in milk as classes of 15 days each, classes of age at parities and season of parity as fixed effects, and cow permanent environment and animal as random effects. Breeding values for sires with daughters with information on MCP were estimated using VCE6 software (*Groeneveld et al.*, 2008). Variances for RCT were set up to 2.780 (genetic), 4.410 (permanent environment) and 6.184 (residual), and those for a_{30} were 15.935 (genetic), 19.860 (permanent environment) and 30.170 (residual). The Intermizoo SpA AI company started in January 2012 to publish a direct selection index (IAC), which combines RCT and a_{30} with equal weight. The index is expressed on a scale with mean 100 and S.d. 5.

Indirect selection index

Currently, direct measures of MCP are available only for cows reared in Veneto region, and EBV are published only for bulls belonging to Intermizoo SpA AI company. The collection of MCP at national level is still under definition and evaluation, and the ANAFI has started to develop an indirect selection index to get round the lack of MCP data, and to point out the attention of milk-producers on those characteristics. A stepwise method was chosen to combine official EBVs of traits published by ANAFI in a selection index able to predict the direct IAC. Only bulls with at least 10 daughters (scored for MCP) in 5 different herds were retained for the regression. The official EBVs considered were those of protein and fat yield, protein and fat content, udder depth, somatic cell score (SCS) and the genetic variants for k-casein. Protein and fat contents, were considered as a combination as reported in the formula that predict cheese yield of Grana Padano cheese at 6 mo of ripening [CYgp = 2.833 + 0.711*genetic base of fat% + EBV fat%) + 0.179*(genetic base of protein% + EBV protein%); see *Aleandri et al.* (1989)].

RESULTS AND DISCUSSION

Descriptive statistics of phenotypic records used for the genetic evaluation of April 2014 is reported in *Table 1*. Mean for milk yield (29.7±9.5 kg/d), fat content (3.85±0.80%) and protein content (3.42±0.43%) of Holstein-Friesian cows reared and sampled in Veneto region are consistent with official national statistics (30.6 kg/d, 3.72% and 3.38%, respectively), reported by *ANAFI* (2014). Rennet coagulation time and a_{30} predicted by MIRS averaged 22.3±5.5 min and 23.0±10.6 mm, in agreement with values reported by *Tiezzi et al.* (2013) who used a sample of data to estimate (co)variance components.

Table 1

Descriptive statistics of milk coagulation properties and production traits of 49,183 cows reared in Veneto region and used to calculate the direct selection index

Trait	Mean	S.d.	CV (%)	Minimum	Maximum
RCT (min)	22.3	5.5	24.6	3.0	40.0
a_{30} (mm)	23.0	10.6	45.8	0.0	60.0
Milk (kg/d)	29.7	9.5	31.9	3.0	92.8
Fat (%)	3.85	0.80	20.82	1.50	9.00
Protein (%)	3.42	0.43	12.43	1.01	6.88
SCS	3.09	1.90	61.39	-3.64	9.64

Table 2

Pearson correlations of EBV for rennet coagulation time (RCT), curd firmness (a_{30}), direct index for milk coagulation ability (IAC) with official selection index (PFT) and EBVs of 683 Holstein bulls

Trait	RCT (min)	a_{30} (mm)	IAC
RCT (min)	-	-0.900	-0.977
a_{30} (mm)	-0.900	-	0.972
IAC	-0.977	0.972	-
Italian Selection index (PFT)	-0.103	0.153	0.130
Milk (kg/d)	0.036^{ns}	-0.152	-0.093
Fat (%)	-0.157	0.258	0.210
Protein (%)	-0.012^{ns}	0.285	0.145
Fat (kg/d)	-0.126	0.125	0.129
Protein (kg/d)	0.030^{ns}	0.041^{ns}	0.004^{ns}
SCS	-0.211	0.170	0.197
Udder composite (ICM)	-0.032	-0.002^{ns}	0.016^{ns}

^{ns}not significantly different from zero

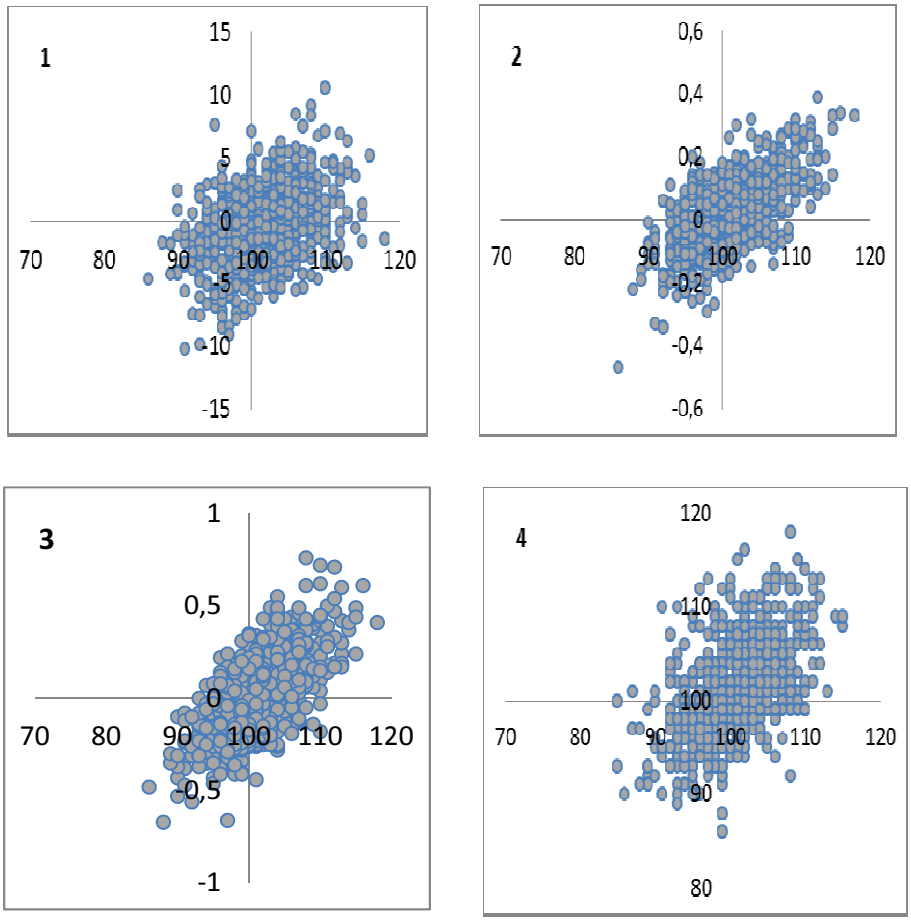
Direct selection index (IAC) showed low to moderate Pearson correlations with the official EBVs published by ANAFI. The highest correlations were with fat content (0.210) and SCS (0.197), and the correlation with the national selection index (PFT) was 0.130 and favourable (*Table 2*). Rennet coagulation time and a_{30} were correlated with the

same strength of the direct index to the EBVs of milk production traits, except for EBVs of milk yield; in this latter case, the relationship between RCT and milk yield was around zero, whereas those of a_{30} and IAC with milk yield were unfavourable and equal to -0.152 and -0.093, respectively.

The final model of the stepwise regression included, as best predictor of IAC, the EBVs of protein and fat content combined in the CYgr, the EBVs of SCS, and a penalty for bulls with "AA" and "AB" genetic variants of k-casein. The rank correlations between the indirect index (ITC) and EBVs for MCP were moderate and equal to -0.23 (RCT), -0.38 (a_{30}) and 0.31 (IAC), thus re-ranking of bulls are expected. The ITC had high correlations with traits used in the regression and equal to 0.58 (protein content), 0.63 (fat content) and 0.54 (SCS; *Figure 1*).

Figure 1

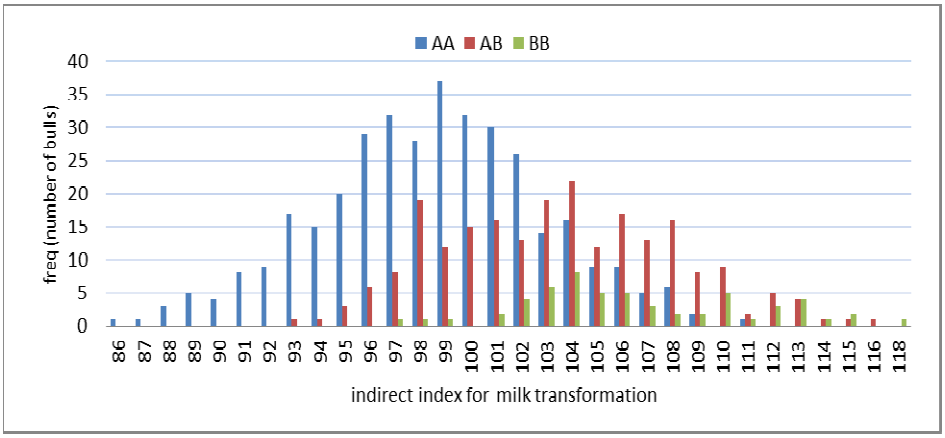
Dispersion plot between EBVs of a_{30} (1), protein content (2), fat content (3) and SCS (4) with the indirect selection idex (ITC) estimated by ANAFI



Bulls with desirable variant of k-casein showed higher ITC, with means of 98.6, 103.5 and 106.6, respectively, for bulls with AA, AB and BB k-casein variants (*Figure 2*).

Figure 2

Distribution of indirect index for milk transformation (ITC) for the genetic variant of k-casein



CONCLUSIONS

Implementation of MIRS models for MCP in the laboratory of Veneto region allows the collection of routine data that can be used as phenotypic records for genetic evaluations due to their genetic variance and importance in the Italian dairy systems. To now, an extensive sampling of traits related to cheese yield was limited because expensive and time consuming, but MIRS technologies provided, also for those traits, an effective and low-cost source of information. The Veneto region experience showed that direct genetic evaluation of MCP is feasible. To start a national genetic evaluation for MCP some efforts are needed: first, other regional laboratories have to install prediction equations of MCP, and then ring test and validation between laboratories have to be routinely performed. When problems related to data collection and data flow will be solved, the bodies responsible for the calculation of official EBVs have to develop the optimal selection index to improve the aptitude of milk to be transformed in cheese.

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