Breeding Value Estimation for Milk Coagulation Properties in the Italian Holstein Friesian Bull Population

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Abstract

Cheese manufacturing is the primary destination of milk produced in Italy. The transformation of milk into cheese is a process consisting of several stages. Coagulation is one of the most important stages, in which milk changes from liquid to gel. Commonly, the main milk coagulation traits studied are milk rennet coagulation time (RCT, min) and curd firmness (a30, mm). Recently, mid-infrared spectroscopy (MIRS) has been applied as a cheap technology to predict milk coagulation properties (MCP) at population level. In the Veneto region, 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 value for milk coagulation properties (IAC) combining RCT and a_{30} in equal weight has been developed using a repeatability single-trait animal model, which included herd-test-day, days-in-milk, age at parity and season of parity as fixed effects, and cow permanent environment and animal additive genetic as random effects. However this direct IAC is not yet available at whole population level, which is mainly due to the absence, up to now, of a collection of individual cow data on a large scale. For this reason, a stepwise approach was chosen in order to combine existing official EBVs for traits published by the Italian Holstein Friesian Cattle Breeders Association (ANAFI) as indirect predictors 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 predictors retained after the regression analyses were the EBVs of protein and fat content, and somatic cell score and the genetic variants for k-casein. The predicted IAC is an official index for ANAFI since December 2013, and is used by the farmers in order to choose those bulls with better cheese capabilities. In the near future it is expected to pass to the direct estimation of IAC at national level.

Key words: Holstein Friesian, cheese, milk coagulation, mid-infrared spectroscopy

Introduction

Modern milk control systems often include mid-infrared spectroscopy (MIRS) as a method to measure milk contents. MIRS is a fast, cheap, and high-throughput method capable of collecting a lot of information and already widely used to predict traditional traits in official milk-recording schemes worldwide.

In recent years research on the possibilities of extracting additional useful information such as new phenotypes from MIRS expanded. MIRS phenotypes show good accuracy of prediction. The new phenotypes can help to respond to changing market requirements. New phenotypes presented are:

- Fatty acid composition
- Milk protein composition
- Melamine content
- Ketone bodies
- Body energy status
- Free amino acid
- Milk technological traits

Several milk technological traits can be used for:

- Quantity of milk products
- Quality of milk products
- Milk payment systems
- Genetics and breeding

Over 70% of Italian milk is used for cheese manufacturing. Economic results of cheese production depend on cheese quantity, cheese quality and also on efficiency of transformation of milk in cheese. Milk coagulation properties (MCP) affect cheese quantity, quality and the efficiency of the cheese-making process and are therefore important milk technological traits. Milk, even with the same processing technique, does not clot in the same way, but factors such as breed, processing company, the production season, the stage of lactation, parity and udder health status affect the coagulation time and the thickness of the clot at the end of the process.

The objective of this work was to define direct and indirect genetic indices for Milk Coagulation Properties in Italian Holstein Friesian sires. This will be discussed here and has been implemented at the Italian Holstein Friesian Cattle Breeders Association (ANAFI).

Material and Methods

Using MIRS with a Lactodynamograph or Formagraph, Figure 1 can be constructed in which some milk coagulation properties are expressed in a graphical manner.

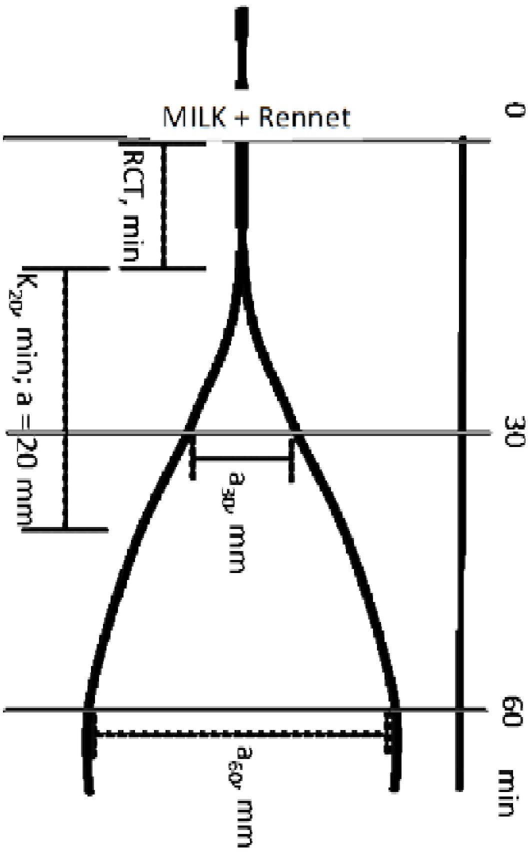

Figure 1. Lactodynamograph displaying milk coagulation measures.

Two measures used here are:

1. Rennet Coagulation Time (RCT) (in min), which measures the amount of time between rennet addition and the beginning of the coagulation process.
2. a_{30}, which measures curd firmness at 30 min after rennet addition. The longer the milk takes to start coagulating, the softer the curd will be at the end of the test, and vice versa.

Cheese manufacturing efficiency depends on the combination of coagulation properties. A repeatability single-trait animal model, which included herd-test-day, days-in-milk, age at parity and season of parity as fixed effects, and cow permanent environment and animal additive genetic as random effects was deployed to obtain estimates for a_{30} and RCT. A direct index for milk coagulation was constructed using standardized values of a_{30} and RCT. The index equally weights a_{30} and RCT and is expressed on a scale with mean 100 and SD 5. In equation form:

$$IAC = 100 + \left(\frac{A_{30} - mean_{A_{30}}}{SD_{A_{30}}} \right) \times 2.5$$
$$- \left(\frac{RCT - mean_{RCT}}{SD_{RCT}} \right) \times 2.5$$

Not all milk laboratories in Italy currently collect the MCP. Therefore as a temporary solution until more laboratories provide MCP measures an indirect index was developed. Correlated traits were used to predict MCP as established in the direct index. A stepwise approach was undertaken in order to combine existing official EBVs for traits published by ANAFI as indirect predictors 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. Following comparisons to evaluate various predictors the following formula was chosen:

ITC = 30% FAT% + 22% PRT% + 32% SCS + 16% K-casein

Fat and protein percentage, somatic cell score and Kappa-Casein genotype were chosen as predictors. Kappa-Casein genotype AA results in a substantial penalty, whereas AB results in a small penalty. Since December 2013 ANAFI computes the indirect cheese transformation index.

Results

Heritability estimates of some milk coagulation properties are shown in Table 1 (Tiezzi *et al.*, 2013).

Table 1. Heritability estimates for milk coagulation traits.

Trait	**RCT (min)**	**a_{30} (mm)**	**IAC**
Heritability	0.210	0.238	>0.200

The correlations between milk coagulation properties and various indices are shown in Table 2 (Battagin *et al.*, 2014).

Table 2. Correlations of milk coagulation traits with EBVs of various other traits[1].

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)	*0.036*	-0.152	-0.093
Fat (%)	-0.157	0.258	0.210
Protein (%)	*-0.012*	0.285	0.145
Fat (kg)	-0.126	0.125	0.129
Protein (kg)	*0.030*	*0.041*	*0.004*
SCS	-0.211	0.170	0.197
Udder composite (ICM)	-0.032	*-0.002*	*0.016*

[1]*Numbers in italics are not significantly different from zero.*

Milk coagulation properties appear to be little correlated with the principal selection criteria. This means that selection on MCP would not need to have negative impact on other important traits.

Discussion and Conclusions

Cheese manufacturing can become more efficient by taking into consideration milk coagulation properties. Increasing milk yield might deteriorate milk coagulation and result in a lower than proportional increase in cheese production. Important points are:

1. MIRS is able to predict milk technological traits.
2. New opportunities for dairy industry to improve the efficiency of cheese and also milk powder production.
3. New opportunities to improve milk payment systems.
4. “New phenotypes” can be used for breeding purposes to improve milk technological aspects and other new important traits (nutritional, healthy features, ...) – addressing consumers requirements.
5. A direct index for MCP can be predicted partly by an indirect index based on correlated traits; however a direct index is preferable.

References

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