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Genetic parameters of different measures of cheese yield and milk nutrient recovery from an individual model cheese-manufacturing process

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ABSTRACT

Cheese yield (CY) is an important technological trait in the dairy industry, and the objective of this study was to estimate the genetic parameters of cheese yield in a dairy cattle population using an individual model-cheese production procedure. A total of 1,167 Brown Swiss cows belonging to 85 herds were sampled once (a maximum of 15 cows were sampled per herd on a single test day, 1 or 2 herds per week). From each cow, 1,500 mL of milk was processed according to the following steps: milk sampling and heating, culture addition, rennet addition, gelation-time recording, curd cutting, whey draining and sampling, wheel formation, pressing, salting in brine, weighing, and cheese sampling. The compositions of individual milk, whey, and curd samples were determined. Three measures of percentage cheese yield (%CY) were calculated: $\%CY_{CURD}$, $\%CY_{SOLIDS}$, and $\%CY_{WATER}$, which represented the ratios between the weight of fresh curd, the total solids of the curd, and the water content of the curd, respectively, and the weight of the milk processed. In addition, 3 measures of daily cheese yield (dCY, kg/d) were defined, considering the daily milk yield. Three measures of nutrient recovery (REC) were computed: REC_{FAT}, $REC_{PROTEIN}$, and REC_{SOLIDS}, which represented the ratio between the weights of the fat, protein, and total solids in the curd, respectively, and the corresponding nutrient in the milk. Energy recovery, REC_{ENERGY}, represented the energy content of the cheese versus that in the milk. For statistical analysis, a Bayesian animal model was implemented via Gibbs sampling. The effects of parity (1 to ≥4), days in milk (6 classes), and laboratory vat (15 vats) were assigned flat priors; those of herd-test-date, animal, and residual were given Gaussian prior distributions. Intra-herd heritability estimates of $\%CY_{CURD}$, $_{\%}CY_{SOLIDS}$, and $\%CY_{WATER}$ ranged from 0.224 to 0.267; these were larger than the estimates obtained for milk yield (0.182) and milk fat content (0.122), and similar to that for protein content (0.275). Daily cheese yields showed heritability estimates similar to those of daily milk yield. The trait $\%CY_{WATER}$ showed a highly positive genetic correlation with $\%CY_{SOLIDS}$ (0.87), whereas their phenotypic correlation was moderate (0.37), and the fat and protein contents of milk showed high genetic correlations with %CY traits. The heritability estimates of $REC_{PROTEIN}$ and REC_{FAT} were larger (0.490 and 0.208, respectively) than those obtained for the protein and fat contents of milk, and the genetic relationships between $REC_{PROTEIN}$ and REC_{FAT} with milk protein and fat content were low or moderate; $REC_{PROTEIN}$ and REC_{FAT} were moderately correlated with the %CY traits and highly correlated with REC_{SOLIDS} and REC_{ENERGY}. Both REC_{SOLIDS} and REC_{ENERGY} were heritable (0.274 and 0.232), and showed high correlations with each other (0.96) and with the %CY traits (0.83 to 0.97). Together, these findings demonstrate the existence of economically important, genetically determined variability in cheese yield that does not depend solely upon the fat and protein contents of milk, but also relies on the ability of the coagulum to retain the highest possible proportions of the available protein, fat, and water. Exploitation of this interesting genetic variation does not seem to be feasible through direct measurement of the phenotype in cows at the population level. Instead, further research is warranted to examine possible means for indirect prediction, such as through assessing the mid-infrared spectra of milk samples.

Key words: individual cheese yield, fat and protein recovery, whey loss, genetic parameter

INTRODUCTION

Cheese production is the most important use of milk produced in many countries (International Dairy Federation, 2011), and the technological parameter of percentage cheese yield (**%CY**; the quantity of cheese obtained from a given quantity of milk processed, expressed as a percentage) is the most important economic trait for the dairy industry and, indirectly, for the definition of price of milk (Emmons, 1993). Nevertheless,

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no previous study has estimated genetic parameters of %CY or its daily cheese yield (**dCY**; the quantity of cheese, in kilograms, obtained from milk yielded by a cow in 1 d). This lack of knowledge can be attributed to 2 main issues: difficulties in individually measuring this trait on a large number of individuals, and the availability of phenotypically correlated traits for the indirect selection of cheese yield.

Cheese is traditionally obtained from the bulk milk of one or more herds. To obtain cheese yield measures at the level of individual animals, a model cheese-making procedure must be set up. This becomes labor intensive because of the many manual steps required, including individual milk sampling; milk analysis; milk weighing and heating; starter culture preparation and addition; pH measurement; rennet preparation and addition; gelation-time recording and curd cutting; whey drainage, sampling, weighing and analyses; curd sampling and analyses; wheel formation; compression; salting; and weighing (Cipolat-Gotet et al., 2013). Moreover, the smaller the volume of the model cheese, the less it represents conditions of industrial cheese-making.

The most important indirect traits used to improve cheese yield (%CY and dCY) are the milk contents of fat and protein (or casein). Almost all of the selection indices for dairy breeds around the world include milk fat and protein content (kg or %; VanRaden, 2004; Miglior et al., 2005). The relative weights of fat and protein contents within these selection indices are often based on the relative economic or technical importance of these 2 nutrients in the dairy industry (Weigel et al., 1997; Rosati and Van Vleck, 2002). The inclusions of fat and protein in the selection indices are based on the following implicit assumptions: (1) different proteins and different fats have the same value; and (2) the recoveries (**REC**) of milk fat and protein in dairy products are constant.

Caseins are the proteins that cause milk to coagulate; they form the basis of cheese production, whereas the other milk proteins remain primarily within the whey. Despite this, caseins are seldom included in selection indices because (1) the casein ratio (the ratio between caseins and total protein) is not very variable (Schopen et al., 2009); and (2) the casein and protein contents present genetic correlations close to unity (Ikonen et al., 2004; Samoré et al., 2012). However, the recovery of milk protein in curd has greater variability than the casein index (Cipolat-Gotet et al., 2013), indicating that some whey proteins can be entrapped in the curd and some caseins can escape coagulation and be lost in the whey. Furthermore, the recovery of milk fat in curd shows some variability that can significantly affect cheese yield (Fagan et al., 2007). The recovery of total solids is influenced by fat and protein recoveries, fat:protein ratio, and the lactose and mineral contents of the curd. Moreover, the recovery of different nutrients influences the recovery of milk energy in curd. Finally, although the compositions and recoveries of the different nutrients determine the total solid cheese yield, cheese yield is also influenced by the ability of the curd to retain water and its solutes.

Cheese yields and nutrient recoveries or whey losses are influenced by many factors, such as milk composition, the technological properties of the milk, the cheese-making process used, and the time and size of curd cutting (Janhøj and Qvist, 2010). However, we have no information on the heritability of these parameters or their genetic correlations with other traits.

The aims of this study were to use model cheeses from individual milk samples in a population of Brown Swiss cows to estimate the genetic parameters for different measures of percentage and daily cheese yields and curd nutrient recoveries (or whey losses), and to estimate their genetic relationships with milk yield and composition.

MATERIALS AND METHODS

Animals and Milk Sampling

Milk samples were obtained from a total of 1,167 Brown Swiss cows from 85 herds (a maximum of 15 cows per herd) located in the Alpine province of Trento (Italy); milk samples were obtained once per cow during evening milking. Within a given day, only a single herd was sampled.

The present study is part of the Cowability–Cowplus projects. Detailed descriptions of the sampling procedure may be found in Cipolat-Gotet et al. (2012) and Cecchinato et al. (2013). Briefly, the collected samples (without preservative) were immediately refrigerated at 4°C and transferred to the Cheese-Making Laboratory of the Department of Agronomy, Food, Natural resources, Animals and Environment (DAFNAE) of the University of Padova (Legnaro, Padova, Italy).

Data on the cows and herds were provided by the Superbrown Consortium of Bolzano and Trento (Italy), and pedigree information was supplied by the Italian Brown Swiss Cattle Breeders Association (ANARB, Verona, Italy). We included cows with phenotypic records available for the investigated traits and all known ancestors. Each sampled cow had at least 4 generations of known ancestors, and the pedigree file included 8,845 animals. The number of sires was 1,326; of these, 264 had progeny with records in the data set (each sire having between 2 and 80 daughters).