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Phenotypic analysis of cheese yields and nutrient recoveries in the curd of buffalo milk, as measured with an individual model cheese-manufacturing process

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ABSTRACT

Traits associated with cheese yield and milk nutrient recovery in curd are used to describe the efficiency of the cheese-making process. This is fundamental for all dairy species, including the Italian Mediterranean buffalo, which is largely used for milk production aimed at the dairy industry. To assess cheese-making traits among buffalo, a model cheese-manufacturing process was tested; it was capable of processing 24 samples per run, using 0.5-L samples of milk from individual buffalo. In total, 180 buffalo reared in 7 herds located in Northeast Italy were sampled once. Briefly, each sample was weighed and heated (35°C for 30 min), inoculated with starter culture (90 min), and mixed with rennet (51.2 international milk-clotting units/L of milk). After 10 min of gelation, the curd was cut; 5 min after the cut, the curd was separated from the whey, and the curd was subjected to draining (for 30 min) and pressing (18 h). The curd and whey were weighed, analyzed for pH and the total solid, fat, lactose, and protein contents, and subjected to estimation of the energy content. Three measures of cheese yield (%CY), $\%CY_{CURD}$, $\%CY_{SOLIDS}$, and $\%CY_{WATER}$, were computed as the ratios between the weight of the curd, the curd dry matter, and the water retained in the curd, respectively, and the weight of the milk processed. These traits were multiplied by the daily milk yield to define the 3 corresponding measures of daily cheese yield (dCY, kg/d). The milk component recoveries (REC) in the curd, REC_{FAT}, $REC_{PROTEIN}$, and REC_{SOLIDS}, represented the ratios between the weights of the fat, protein, and total solids in the curd, respectively, and the corresponding components in the milk. Finally, energy recovery (REC_{ENERGY}) was estimated. The values for $\%CY_{CURD}$, $\%CY_{SOLIDS}$, $\%CY_{WATER}$, $REC_{PROTEIN}$, REC_{FAT}, REC_{SOLIDS}, and REC_{ENERGY} averaged 25.6, 12.7, 12.9, 80.4, 95.1, 66.7, and 79.3%, respectively, indicating that buffalo milk has a higher aptitude to cheese-making than bovine milk. The effect of days in milk was the most important source of variation for %CY, $REC_{PROTEIN}$, and the overall recoveries (which showed higher values toward the end of lactation), whereas parity did not appear to influence any of the investigated traits. The cheese-making procedure tested allowed us to assess the variability of and relationships among different cheese yield traits, recovery traits, daily milk production traits, and milk components at the individual level.
Key words: buffalo milk, cheese-making trait, individual cheese yield, whey loss

INTRODUCTION

The buffalo (*Bubalus bubalis*) is the second most important dairy species, providing 13% of the total milk produced worldwide (FAOSTAT, 2014). In Italy, the Mediterranean buffalo breed has been selected for milk production and quality. Traditionally, buffalo dairy farms are concentrated in Southern Italy, where "Mozzarella di Bufala Campana," an Italian protected designation of origin (**PDO**) cheese, is produced; however, the buffalo population has expanded to different regions of the country in recent years (Tiezzi et al., 2009). In fact, the Italian buffalo population, registered in national the herd book, has increased by 36% over the past decade (ANASB, 2013), mainly because of the absence of a quota system for milk production and the higher price of buffalo milk.

Currently, the selection program of the National Association of Buffalo Breeders is based on the PKM index, which estimates the mozzarella cheese (kg) produced per lactation (Rosati and Van Vleck, 2002) by using formulas to predict cheese yield (**%CY**), as introduced by Altiero et al. (1989). The prediction equations used to estimate %CY are normally based on the contents of milk protein (or its fractions) and fat (Van Slyke and Price, 1952; Banks et al., 1981; Emmons et al., 1990), and assume that their recoveries in the curd are constant. However, in an analysis of model cheeses made from individual milk samples, Cipolat-

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Gotet et al. (2013) demonstrated that the whey losses/curd recoveries (**REC**) of bovine milk components were not constant, and were influenced by individual causes of variation (e.g., the stage of lactation and order of parity). Using the same dataset, Bittante et al. (2013a) observed that both %CY and REC are genetically controlled, whereas Ferragina et al. (2013) proposed that Fourier-transform infrared spectroscopy-based predictions could be used to monitor the cheese-making ability of cow milk at the individual level. Zicarelli et al. (2007a) estimated %CY from individual buffalo milk samples, and showed higher values for actual %CY compared with those predicted (Altiero et al., 1989). Although a few studies have examined the %CY of buffalo milk (Di Palo et al., 2007; Napolano et al., 2007; Zicarelli et al., 2007b), the cheese-making efficiency of buffalo milk has not been fully investigated at the individual level, and no previous study has elucidated the factors that affect the variability of nutrient recovery in the cheese/loss in the whey in this system.

Given these gaps in the literature, the present study sought (1) to characterize individual buffalo %CY and REC (protein, fat, solids, and energy) in the curd using a model cheese-manufacturing process; (2) to estimate the daily production of cheese (**dCY**; kg/d) at the individual level; (3) to compare the cheese-making aptitude of buffalo milk versus that of cow milk; and (4) to investigate several potential sources of variation for these traits using individual model cheeses made from buffalo milk.

MATERIALS AND METHODS

Data Collection and Analysis

Milk samples were collected once from 180 buffalo cows reared in 7 herds located in Northeast Italy (Veneto and Friuli-Venezia Giulia regions) between December and April. Buffaloes were selected from each herd to represent the entire lactation and different parity order. During the evening milking, an individual milk sample from each buffalo was collected (in a stainless-steel vat; sampling of 1,000 L of milk/buffalo, divided in 2 disposable plastic containers, both of 500-mL capacity) without preservative. All samples were immediately cooled to 4°C, stored in portable refrigerators (4°C) and transferred to the Milk Laboratory of the Department of Agriculture, Food, Natural Resources, Animals and Environment (University of Padova, Legnaro, Italy). All the samples were analyzed within 20 h after collection.

From one subsample, 50 mL was used to measure milk quality traits (total solids, fat, protein, casein, and lactose) by using a MilkoScan FT2 (Foss, Hillerød, Denmark). The SCC of each sample was obtained using a Fossomatic FC counter (Foss) and log-transformed to SCS, as proposed by Ali and Shook (1980). All the samples were analyzed after heating to 35°C. Data on the buffaloes, herds, and single test-day milk yield were provided by the breeders' associations of the Veneto (Associazione Regionale Allevatori del Veneto) and Friuli Venezia-Giulia (Associazione Allevatori del Fruili Venezia Giula) regions.

Individual Model Cheese-Manufacturing Procedure

A laboratory micro cheese-making method previously proposed for the assessment of %CY and the recovery of milk constituents in the curd (Cologna et al., 2009) was used to process the individual buffalo milk samples. The cheese-making apparatus consisted of 3 water baths (**WB**) fitted with a digital temperature controller and water pumps to ensure homogeneous heat distribution. Each WB received 8 stainless steel vats (capacity, 500 mL); thus, the apparatus allowed us to process up to 24 individual milk samples (3 WB × 8 vats) per cheese-making session (1 d).

Each buffalo milk sample (500 mL) was subjected to the following procedure (Figure 1). The milk was heated to 35°C (30 min), and after the reaching of this temperature, the pH was recorded using a Crison Basic 20 electrode (Crison, Barcelona, Spain), and starter cultures were inoculated into the samples. The starter cultures consisted of an industrial freeze-dried formulation of thermophilic lactic bacteria (Delvo-Tec TS-10A DSL; DSM Food Specialties, Delft, the Netherlands); the cultures were concentrated to 8-fold higher than the recommended level, to reduce the acidification time to 90 min, and calf rennet solution [3.2 mL per sample, consisting of 0.16 mL of Hansen standard 160, 80 ± 5% chymosin, and 20 ± 5% pepsin; 160 international milk clotting units/mL (Pacovis Amrein AG, Bern, Switzerland) diluted 20-fold in distilled water] was added. Ten minutes after the operator observed the initiation of milk gelation, the curd was cut into cubes of about 0.5 cm^3. Five minutes after the cut, the curd was separated from the whey and suspended over the whey-containing vat in a stainless-steel cheese mold. Thirty minutes later, the curd was turned, and then it was pressed for 18 h at room temperature using a 1-kg weight.

After pressing, the curd and whey were weighed (g) and the whey components (total solids, fat, protein, lactose) and acidity (pH) were determined using a MilkoScan FT2 (Foss, Hillerød, Denmark) and a Crison Basic 20 electrode (Crison, Barcelona, Spain), respectively. These data were used to calculate various cheese-making efficiency traits, as previously described by Cipolat-Gotet et al. (2013). Briefly, $\mathbf{\%CY_{CURD}}$,