J. Dairy Sci. 101:1–20
https://doi.org/10.3168/jds.2018-14566

Grazing of dairy cows on pasture versus indoor feeding on total mixed ration: Effects on low-moisture part-skim Mozzarella cheese yield and quality characteristics in mid and late lactation

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ABSTRACT

This study investigated the effects of 3 dairy cow feeding systems on the composition, yield, and biochemical and physical properties of low-moisture part-skim Mozzarella cheese in mid (ML; May–June) and late (LL; October–November) lactation. Sixty spring-calving cows were assigned to 3 herds, each consisting of 20 cows, and balanced on parity, calving date, and pre-experimental milk yield and milk solids yield. Each herd was allocated to 1 of the following feeding systems: grazing on perennial ryegrass (*Lolium perenne* L.) pasture (GRO), grazing on perennial ryegrass and white clover (*Trifolium repens* L.) pasture (GRC), or housed indoors and offered total mixed ration (TMR). Mozzarella cheese was manufactured on 3 separate occasions in ML and 4 in LL in 2016. Feeding system had significant effects on milk composition, cheese yield, the elemental composition of cheese, cheese color (green to red and blue to yellow color coordinates), the extent of flow on heating, and the fluidity of the melted cheese. Compared with TMR milk, GRO and GRC milks had higher concentrations of protein and casein and lower concentrations of I, Cu, and Se, higher cheese-yielding capacity, and produced cheese with lower concentrations of the trace elements I, Cu, and Se and higher yellowness value. Cheese from GRO milk had higher heat-induced flow and fluidity than cheese from TMR milk. These effects were observed over the entire lactation period (ML + LL), but varied somewhat in ML and LL. Feeding system had little, or no, effect on gross composition of the cheese, the proportions of milk protein or fat lost to cheese whey, the texture of the unheated cheese, or the energy required to extend the molten cheese. The differences in color and melt characteristics of cheeses obtained from milks with the different feeding systems may provide a basis for creating points of differentiation suited to different markets.
Key words: pasture, total mixed ration, milk, Mozzarella

INTRODUCTION

Milk composition is a key factor affecting cheese yield, the recoveries of fat and protein from milk to cheese, and, hence, the profitability of manufacturing plants (Fox et al., 2017). Consequently, the effects of differences in the concentration of milk constituents, especially fat and protein, on cheese yield and component recoveries have been investigated extensively (Fox et al., 2017). In many of these studies, the concentrations of protein and fat in milk have been altered by process intervention, for example by low-concentration factor membrane filtration (Govindasamy-Lucey et al., 2005, 2007; Ong et al., 2013; Soodam et al., 2014), addition of low-heat skim milk powder or buttermilk powder, or standardization to different protein-to-fat ratios in the manufacturing of reduced-fat cheese variants (Fenelon and Guinee, 1999). The focus of many of these studies was to simulate the potential effects of seasonal changes in milk protein concentration, especially in milk from dairy herds composed of spring-calving cows grazed on pasture, as opposed to milk from herds of year-round calving of cows fed indoors on preserved forages supplemented with concentrates. As milk for cheese manufacturing is generally standardized to a fixed protein-to-fat ratio to ensure compliance to compositional specifications and consistent quality, variation of fat content in raw milk is of little relevance in large-scale modern cheese manufacture.

Increasing milk protein in the range of 3.0 to 4.5% when maintaining a standard protein-to-fat ratio gener-

Received February 9, 2018.
Accepted June 25, 2018.
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ally results in higher cheese yield, but has little effect on protein recovery or cheese composition (Soodam and Guinee, 2018). The magnitude of the effect depends on the degree to which the protein concentration is increased and cheesemaking conditions (Soodam and Guinee, 2018). Reducing protein-to-fat ratio of milk, by changing fat content in the range of 0.1 to 3.5% (wt/wt), has pronounced effects, the most notable being an increase in cheese firmness and fracture stress, impairment of cooking properties, and a deterioration in sensory qualities (e.g., a loss of typical cheese flavor and creaminess). As for protein, the effects of altering fat content depend on the degree of fat reduction and manufacturing procedure (Rudan et al., 1999; Fenelon and Guinee, 2000; Henneberry et al., 2015, 2016; McCarthy et al., 2016).

Auldist et al. (2016) investigated the effect of varying the type and quantity of supplement (wheat grain, corn grain, canola meal, alfalfa hay) to cows grazed on perennial ryegrass. Altering the diet affected milk fat content, fatty acid profile, and cheese yield, but not milk protein concentration, protein profile, or rennet gelation properties. More recently, O'Callaghan et al. (2016, 2017) reported on the effect of feeding system on milk composition and Cheddar cheese, where cows were grazed on pasture, either perennial ryegrass or perennial ryegrass with white clover, or offered a TMR indoors. Significant effects of feeding system were observed for milk composition, fatty acid profile, color, hardness, and sensory characteristics of the cheese. Cheese from milk produced by the pasture-feeding systems had higher concentrations of β-carotene, lower weight proportions (g/100 g of milk fat) of palmitic (C16:0) and linoleic (C18:2c) acids, a higher proportion of linolelaidic acid (C18:2-*trans*), and were softer at 20°C and more yellow in color (O'Callaghan et al., 2017).

Mozzarella and Cheddar represent the cheese varieties produced in the largest quantities in the United States (USDA, 2018), primarily because of their use as an ingredient in foods such as sandwiches and pizza. In these applications, the physical characteristics of the unheated and heated cheese are key determinants of quality. Auldist et al. (2010) compared the properties of Cheddar cheese from milk from cows on extended lactation [up to 670 d in lactation (**DIL**)] and fed indoors on TMR or grazed on pasture grass supplemented with grain (barley and triticale) and alfalfa silage and hay. Apart from milk from TMR-fed cows having a slightly, but significantly, lower proportion of α_{S1}-CN and concentration of phosphorous, feeding system had no effect on milk composition, cheese composition, cheese yield, recovery of milk fat or protein to cheese, or grading scores received for flavor and texture. We are unaware of any studies on the comparative effects of TMR and pasture-based feeding systems on Mozzarella cheese. The current study compared pasture- and TMR-based feeding systems for their effects on composition, yield, color, texture and thermophysical properties of low-moisture part-skim Mozzarella (**LMPS**) cheese manufactured in mid lactation or late lactation. Milk was obtained from 3 spring-calving herds, each assigned to 1 of 3 feeding systems.

MATERIALS AND METHODS

Feeding Systems and Milk Collection

Sixty spring-calving dairy cows from the Teagasc Moorepark herd with a mean calving date of February 19, 2015, were allocated to 1 of 3 different feeding systems: grazing on perennial ryegrass (*Lolium perenne* L.) pasture (**GRO**), grazing on perennial ryegrass and white clover (*Trifolium repens* L.) pasture (**GRC**), or housed indoors and offered a TMR, as described by O'Callaghan et al. (2016) and Gulati et al. (2018). The average sward clover content across the year was 23.8% of herbage DM. The herds were each composed of 20 cows and were balanced for breed (16 Holstein Friesian + 4 Holstein Friesian × Jersey), lactation number (4 primiparous + 16 multiparous), calving date, and 2-wk pre-experimental milk yield and milk solids yield. The cows were placed on the different feeding systems 1 wk after calving, and individual cows were maintained on the treatments until the milk yield dropped to <8 L/d or until November 29, 2016.

As described previously (Gulati et al., 2018), the grazing treatments (GRO, GRC) were stocked at 2.75 livestock units/ha and were rotationally grazed at a frequency of 8.3 grazing rotations per season. Cows were retained on pasture (grass or grass with white clover) paddocks until a minimum postgrazing sward height of 4 cm. Cows on the GRO or GRC pastures had a daily DMI of 18 kg/cow. The TMR diet has been described in detail by O'Callaghan et al. (2016). It comprised grass silage, maize silage, and concentrates, including beet pulp, soybean meal, maize distillers grains, rolled barley, rapeseed meal, Megalac, acidbuf, and mineral balancer (McDonnell Bros. Agricultural Suppliers Ltd., Fermoy, Co. Cork, Ireland). The daily DMI of TMR-fed cows was 7.15 kg of grass silage, 7.15 kg of maize silage, and 8.3 kg of concentrate. The concentrate portion of the TMR feed was fortified with a commercial mineral balancer (Dairy Hi-Phos; McDonnell Bros. Agricultural Suppliers Ltd., Fermoy, Co. Cork, Ireland), giving added levels of Ca, Na, P, Zn, Cu, Mn, I, Co, and Se of 3,340, 2,000, 1,200, 140, 100, 70, 10, 2, and 0.8 mg/kg, respectively. Cows on all feeding systems were offered water fortified with a liquid mineral supplement