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Effect of pasture versus indoor feeding systems on raw milk composition and quality over an entire lactation

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ABSTRACT

The aim of this study was to investigate the effects of different feeding systems on milk quality and composition. Fifty-four multiparous and primiparous Friesian lactating cows were divided into 3 groups (n = 18) to study the effects of 3 feeding systems over a full lactation. Group 1 was housed indoors and offered a total mixed ration diet (TMR), group 2 was maintained outdoors on a perennial ryegrass pasture (referred to as grass), and group 3 was also grazed outdoors on a perennial ryegrass/white clover pasture (referred to as clover). Bulk milk samples were collected from each group at morning and afternoon milkings once weekly from March 11 to October 28 in 2015. Milk from pasture-fed cows (grass and clover) had significantly higher concentrations of fat, protein, true protein, and casein. The pasture feeding systems induced significantly higher concentrations of saturated fatty acids $C_{11:0}$, $C_{13:0}$, $C_{15:0}$, $C_{17:0}$, $C_{23:0}$, and unsaturated fatty acids $C_{18:2n\text{-}6trans}$, $C_{18:3n\text{-}3}$, $C_{20:1}$, and $C_{20:4n\text{-}6}$ and a greater than 2-fold increase in the conjugated linoleic acid $C_{18:2cis\text{-}9trans\text{-}11}$ content of milk compared with that of the TMR feeding system. The TMR feeding system resulted in milks with increased concentrations of $C_{16:0}$, $C_{18:2n\text{-}6c}$, $C_{18:3n\text{-}6c}$, $C_{22:0}$ $C_{22:1n\text{-}9}$, and $C_{18:2cis\text{-}10trans\text{-}12}$. Principal component analysis of average fatty acid profiles showed clear separation of milks from the grazed pasture-based diets to that of a TMR system throughout lactation, offering further insight into the ability to verify pasture-derived milk by fatty acid profiling.

Key words: pasture, total mixed ration, milk composition, dairy cow, diet

INTRODUCTION

Farming practices are primarily dictated by a region's climate and resources. The Irish dairy industry, like New Zealand, has a temperate climate and is based around the use of pasture as a low-cost primary feed source (O'Brien et al., 1999); as a result temperate regions have a seasonal milk supply. Typically, in pasture-based feeding systems, cows are maintained outdoors grazing fresh pasture during the warmer months and are dried off and housed indoors in the winter months leading up to the spring calving period. Dairy products derived from pasture-based systems are considered by consumers to be more natural as a result of increased animal welfare and protection of the environment (Verkerk, 2003). Pasture systems also offer cows a more natural environment, which allows the expression of normal behaviors (Legrand et al., 2009; Charlton et al., 2011). Total mixed ration, year-round indoor housing systems are widely practiced in the United States and parts of Europe as the major farming systems (van Arendonk and Liinamo, 2003; Barberg et al., 2007). Such systems involve feeding cows a TMR diet, composed of a mix of grass/maize/corn silage, carbohydrates, and concentrates, which better enable high milk production per cow through greater control of feed intake quality and increased daily DMI (Charlton et al., 2011). Indoor TMR systems also offer the cows protection from environmental extremes such as heat, cold, and wetness (Legrand et al., 2009). Such systems have been linked with animal welfare concerns such as increased lameness, reduced comfort, and an increased prevalence of mastitis, all of which can have an effect on animal production (Haskell et al., 2006; Fregonesi et al., 2007).

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The effect of cows' dietary system on milk composition has received much attention in the past and it is widely accepted that feeding system has significant effects on milk fatty acid (**FA**) composition with particular emphasis on the health-benefiting UFA components, particularly CLA. Examples of feeding systems that have been studied for their effects on milk include consumption of TMR (White et al., 2001), red clover (Lee et al., 2009), red clover and grass silage (Moorby et al., 2009), fresh alfalfa (Castillo et al., 2006), alfalfa silage (Whiting et al., 2004), linseed (Puppel et al., 2013), fresh forage and marine algae (Glover et al., 2012), camelina (Hurtaud and Peyraud, 2007), fish oil (Baer et al., 2001), fish oil and extruded soybeans (Ramaswamy et al., 2001), rapeseed supplementation (Stanton et al., 1997), and various proportions of fresh grass (Couvreur et al., 2006). Research has clearly identified that incorporating white clover into pasture-based diets has many benefits on dairy cow performance due to its increased nutritive value over perennial ryegrass (Ribeiro Filho et al., 2005; Egan et al., 2015; McCarthy et al., 2016). Feeding pure white clover, however, is not a feasible practice due to difficulties in maintaining such swards and increased risk of bloat (Harris et al., 1998). The clover level needed to induce a beneficial response on a cow's performance has also been studied with mixed results. Thomson (1984) indicated that clover content needed to be at least 30%, Egan et al. (2015) found benefits at sward clover contents of 23%, whereas studies performed in New Zealand reported 50 to 60% clover content to be more appropriate to increase milk yields significantly (Harris et al., 1997, 1998). Caradus et al. (1996) outlined the major benefits associated with clover feeding, which include its improved sward quality, improved forage DMI and utilization rates in animals, and effectiveness at fixing N in the soil.

It is understood that milk from cows consuming significant quantities of grazed grass contains higher proportions of UFA and CLA than cows that are offered diets dominated by conserved forages, concentrates, and grains (Kelly et al., 1998). Much of this research, however, was conducted over a short period using crossover studies or replicated Latin square designs. Limited information is available for the comparison of pasture-based and TMR feeding systems on the composition and quality of raw milk over an entire lactation season.

The objective of this study was to examine and assess the effects of 3 widely practiced feeding systems, namely a TMR diet indoors, perennial ryegrass (*Lolium perenne* L.) outdoors (**GRS**), and perennial ryegrass/white clover (*Trifolium repens* L.) outdoors (**CLV**) on the composition and quality of raw milk throughout an entire lactation, and to identify potential attributes of milks that could be used to verify pasture-derived milks.

MATERIALS AND METHODS

Reagents

Hexane, heptane, formic acid, and 25% sodium methoxide were purchased from Sigma Aldrich (Dublin, Ireland). Diethyl ether was purchased from Fisher Scientific (Dublin, Ireland). Internal standard trinonadecanoin ($C_{19:0}$; part number: T-165) and a standard mix of conjugated linoleic acid $C_{18:2,c9t11}$ and $C_{18:2,c10t12}$ (part number: UC-59M) were purchased from Nu-Chek Prep Inc. (Elysian, MN; c = *cis*; t = *trans*). Fatty acid methyl ester standard mix containing $C_{4:0}$-$C_{24:0}$ methyl esters (part no: 18919–1AMP) was purchased from Sigma Aldrich (Dublin, Ireland).

Experimental Design and Sample Collection. Fifty-four spring-calving Friesian cows were allocated to 3 groups (n = 18) at the Teagasc Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland. The experiments were conducted between March 11 and October 28, 2015. Groups were randomized based on milk yield, milk solids yield, calving date (mean calving date February 19, 2015), and lactation number. Three feeding systems were compared over a full lactation; group 1 was housed indoors and fed a TMR diet, group 2 was maintained outdoors on perennial ryegrass only pasture (GRS), whereas group 3 was also maintained outdoors on a perennial ryegrass/white clover pasture (CLV). The TMR diet consisted of, on a DM basis, 7.15 kg of grass silage, 7.15 kg of maize silage, and 8.3 kg of concentrates (see Tables 1 and 2). Cows within the TMR system were fed at 0830 h daily into electronically controlled Griffith Elder Mealmaster individual feed bins (Griffith Elder and Company Ltd., Suffolk, UK) and was available ad libitum. Pasture-based cows consumed ~18 kg of DM/d (see Table 3) measured by pre- and postgrazing sward heights daily using the rising plate meter (Jenquip, Fielding, New Zealand), whereas pregrazing herbage mass was measured with an Etesia mower (Etesia UK Ltd., Warwick, UK). The CLV sward contained 20% clover and was measured according to Egan et al. (2013). Milking took place at 0730 and 1530 h daily, and milk yields were recorded using DairyMaster milk meters (DairyMaster, Kerry, Ireland). To obtain a representative sample of milk, the cows in each of the 3 feeding systems were milked separately into designated 5,000-L refrigerated tanks. The evening milk was stored at 4°C overnight, to which the morning milk was then added and agitated before collection. Bulk milk samples were collected