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Outdoor grazing of dairy cows on pasture versus indoor feeding on total mixed ration: Effects on gross composition and mineral content milk during lactation[1]

Arunima Gulati,* Norann Galvin,† Eva Lewis,† Deirdre Hennessy,† Michael O'Donovan,† Jennifer J. McManus,‡ Mark A. Fenelon,* and Timothy P. Guinee*[2]
*Teagasc Food Research Centre Moorepark, Fermoy, Co. Cork, Ireland
†Teagasc, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland
‡Department of Chemistry, National University of Ireland Maynooth, Maynooth, Co. Kildare, Ireland

ABSTRACT

The influence of feeding system and lactation period on the gross composition, macroelements (Ca, P, Mg, and Na), and trace elements (Zn, Fe, Cu, Mo, Mn, Se, and Co) of bovine milk was investigated. The feeding systems included outdoor grazing on perennial ryegrass pasture (GRO), outdoor grazing on perennial ryegrass and white clover pasture (GRC), and indoors offered total mixed ration (TMR). Sixty spring-calving Holstein Friesian dairy cows were assigned to 3 herds, each consisting of 20 cows, and balanced with respect to parity, calving date, and pre-experimental milk yield and milk solids yield. The herds were allocated to 1 of the 3 feeding systems from February to November. Milk samples were collected on 10 occasions over the period June 17 to November 26, at 2 or 3 weekly intervals, when cows were on average 119 to 281 d in lactation (DIL). The total lactation period was arbitrarily subdivided into 2 lactation periods based on DIL, namely mid lactation, June 17 to September 9 when cows were 119 to 203 DIL; and late lactation, September 22 to November 26 when cows were 216 to 281 DIL. With the exception of Mg, Na, Fe, Mo, and Co, all other variables were affected by feeding system. The GRO milk had the highest mean concentrations of total solids, total protein, casein, Ca, and P. The TMR milk had the highest concentrations of lactose, Cu, and Se, and lowest level of total protein. The GRC milk had levels of lactose, Zn, and Cu similar to those of GRO milk, and concentrations of TS, Ca, and P similar to those of TMR milk. Lactation period affected all variables, apart from the concentrations of Fe, Cu, Mn, and Se. On average, the proportion (%) of total Ca, P, Zn, Mn, or Se that sedimented with the casein on high-speed ultracentrifugation at 100,000 × g was ≥60%, whereas that of Na, Mg, or Mo was ≤45% total. The results demonstrate how the gross composition and elemental composition of milk can be affected by different feeding systems.
Key words: pasture, total mixed ration, milk, element

INTRODUCTION

The composition of bovine milk is influenced by various factors including stage of lactation, nutrition, health status, lactation number, and proportions of cows in a herd calving at different times of the year (O'Brien et al., 1999a,b; O'Callaghan et al., 2016b). The most widely used feeding methods for dairy cows globally include outdoor grazing on pasture, usually with a low quantity of concentrate supplementation offered only at the extremes of the pasture-growing season, or indoors offered TMR composed mainly of silage, grain, and added vitamins and minerals. Pasture-based feeding is common in temperate regions where pasture growth is abundant, including Ireland, New Zealand, and parts of Australia, whereas TMR is used more extensively in the United States, parts of Europe, and the southern hemisphere (O'Callaghan et al., 2017). Pasture composition can vary with region, but generally includes perennial ryegrass (*Lolium perenne* L.) with other species such as clover (*Trifolium repens* L.), meadow grass (*Poa trivialis* L.), cocks's foot (*Dactylis glomerata* L.), and fescue (*Festuca arundinacea* L.; O'Mara, 2008). The composition of TMR can vary according to the type and ratio of different feed materials included in the formulation.

Advantages of pasture-based feeding include its cost competiveness, its lower contribution to enteric methane emissions (O'Neill et al., 2011), and provision of a "more natural" environment for animal welfare (Verkerk, 2003). Additional advantages of pasture in-

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[2]Corresponding author: tim.guinee@teagasc.ie

corporating clover include atmospheric N fixation and reduction in nitrous oxide emissions (Ledgard et al., 2009). Advantages of TMR include a more consistent feed composition and quality, better regulation of DMI, and higher milk yield (Kolver and Muller, 1998; McAuliffe et al., 2016).

Several studies have compared the effects of pasture and TMR feeding systems on yield of milk and gross composition. Milk produced using TMR-based feeding has lower concentrations of TS, fat, total protein, true protein, and casein compared with milk from pasture-fed cows (O'Callaghan et al., 2016b). Nevertheless, TMR feeding results in higher milk yield, and despite the lower concentrations of TS, a higher yield of milk fat and protein (Kolver and Muller, 1998; McAuliffe et al., 2016). Despite the widespread use of pasture and TMR feeding systems, there is a paucity of published information on the comparative effects of these feeding systems on milk characteristics other than gross composition, such as the profile of proteins and minerals. Minerals such as Ca and P are important modulators of protein-protein interactions, casein micelle structure, and the susceptibility of the protein to aggregation during dairy processing (Holt and Jenness, 1984). Consequently, Ca and P have a major influence on processing characteristics, such as rennet coagulation, heat stability, and ethanol stability (Tsioulpas et al., 2007; Sandra et al., 2012; Horne, 2016). Apart from their effects on protein aggregation (Sievanen et al., 2008; Sandra et al., 2012), variation in mineral content can also alter the nutritional value of milk and milk products (Cashman, 2011a). The role of trace elements in human nutrition has been extensively reviewed (Cashman, 2011b; Gaucheron, 2013); they contribute biological and physiological functions such as the role of Fe in hemoglobin production, Cu and Se in enzyme functioning, Co as a constituent of vitamin B_{12}, and Se as a component of glutathione peroxidase, an antioxidant. Further, little is known how trace elements partition between the casein and serum phases of milk, even though this is likely to influence their bioavailability (Cashman, 2011b). Protein and minerals (elements) in first stage (0–6 mo) infant milk formula (**IMF**) and follow-on formula are provided by the skim milk powder and whey ingredients used in formulation. The total concentration of elements in the latter ingredients determines the level of element fortification required to meet the target label claim for the IMF and follow-on formula (European Commission, 2006; McSweeney et al., 2013; McCarthy et al., 2016). Hence, any changes in the concentrations of protein and elements owing to the feeding system of the dairy cow and stage of lactation could necessitate reformulation of the IMF and affect in-process thermal stability.

The current study was undertaken as part of an overall project collaboration, "Profiling milk from Grass," between Teagasc Food Research Centre Moorepark and Teagasc Animal & Grassland Research and Innovation Centre Moorepark to address knowledge gaps on the comparative effects of pasture and TMR feeding systems. Recent studies have described the influence of these feeding systems on milk yield (McAuliffe et al., 2016), milk fat composition (O'Callaghan et al., 2016b), and butter quality (O'Callaghan et al., 2016a). The current study investigated the effect of the following feeding systems on the gross composition and concentrations of macroelements and trace elements in milk over the period June to November 2015: outdoor grazing on perennial ryegrass pasture (**GRO**), outdoor grazing on perennial ryegrass and white clover pasture (**GRC**), and indoors offered TMR.

MATERIALS AND METHODS

Details of Herd and Feeding Systems

Sixty spring-calving dairy cows were allocated to 1 of the 3 groups at the Teagasc Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland, in 2015. Each treatment group consisted of 20 cows and the groups were balanced with respect to breed (48 Holstein Friesian + 12 Holstein Friesian × Jersey), lactation number (12 primiparous + 48 multiparous), calving date (mean calving date February 19, 2015) and pre-experimental milk yield and milk solids yield, as described by McAuliffe et al. (2016). The average Economic Breeding Index value (www.icbf.com) of the 3 herds was €185 (SD = ±€43). The feeding systems, imposed from mid February [1 d in lactation (**DIL**)] to November (300 DIL), were outdoor grazing on perennial ryegrass (*Lolium perenne* L.) pasture (GRO), outdoor grazing on perennial ryegrass and white clover (*Trifolium repens* L.) pasture (GRC), or indoors offered TMR (TMR).

The GRO and GRC swards were fertilized at 250 kg of N/ha per yr. Nitrogen was applied to GRO and GRC swards treatments as urea (46% N) until the end of April and as calcium ammonium nitrate (27% N) from early May to mid September. The grazing treatments were stocked at 2.75 livestock units/Ha in a fully closed farm system. Both grazing groups were rotationally grazed, achieving 8.3 grazing rotations in the season. Cows remained in their treatment groups for the entire lactation. Grass was allocated to the grazing groups each day to achieve a postgrazing sward height of 4 cm. Pasture allocation for the grazing treatments was measured using pre-grazing herbage mass (>4 cm) and area (m^2). Average sward clover content across the