J. Dairy Sci. 107:8058–8071
https://doi.org/10.3168/jds.2023-24517

Intake profile, milk production, and energy balance of early-lactation spring-calving Holstein Friesian and Jersey × Holstein Friesian dairy cows in high-utilization pasture-based systems

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ABSTRACT

Early lactation is a critical period for dairy cows, as energy requirements rapidly increase with the onset of lactation; however, early-lactation DMI in pasture-based systems are under measured. The objectives of this study were (1) to measure and profile total DMI (TDMI) and animal performance of dairy cows during early lactation in a pasture-based system, (2) to investigate early-lactation energy balance in pasture-based systems, and (3) to examine production efficiencies, including TDMI and milk solids production per 100 kg of BW. Eighty spring-calving dairy cows were allocated to a grazing group as they calved over a 2-yr period (2021 and 2022). Cows were offered a daily herbage allowance to achieve a postgrazing sward height of 4 cm, with silage supplementation when necessary due to inclement weather. Total DMI was measured using the n-alkane technique over a 12-wk period from February 1, 2021, to April 23, 2022. Total DMI and daily milk yield were significantly affected by parity with both variables being greatest for third-parity animals (17.7 kg of DM and 26.3 kg/cow per day, respectively), lowest for first parity (13.2 kg of DM and 19.6 kg/cow per day, respectively) and intermediate for second-parity animals (16.8 kg of DM and 24.1 kg/cow per day, respectively). Peak TDMI was reached on wk 10 for first-parity animals (14.6 kg of DM), wk 11 for second parity animals (19.3 kg of DM) and wk 12 for third-parity animals (19.9 kg of DM). Parity also had a significant effect on unité fouragère lait (UFL; feed units for milk) feed balance as first-parity animals experienced a greater degree of negative energy balance (−3.2 UFL) compared with second- and third-parity animals (−2.3 UFL). Breed and parity had an effect on production efficiencies during the first 12 wk of lactation as Jersey × Holstein Friesian cows had greater TDMI/100 kg of BW and milk solids/100 kg of BW compared with Holstein Friesian cows.

Key words: dry matter intake, early-lactation intake profile, dairy cow efficiency, negative energy balance

INTRODUCTION

A major objective of pasture-based dairy systems is to maintain high levels of both grazing utilization and milk production (Ganche et al., 2013). Grazed grass is the cheapest feed source available on Irish dairy farms (Doyle et al., 2022), and therefore, maintaining sward quality and high levels of grass in the diet through high sward utilization is a key performance indicator of Irish grassland farms (O'Donovan et al., 2021). The seasonality of grass growth in Ireland results in little growth over winter due to low temperatures and low levels of sunlight, while peak grass supply occurs in late spring and early summer (Hurtado-Uria et al., 2013). As a result, 73% of Irish dairy cows calve between January and March (ICBF, 2022), allowing for peak milk production to coincide with increasing grass growth rates (Dillon et al., 1995). Spring grass is a highly nutritious feed for dairy cows due to its high digestibility and CP content (Kennedy et al., 2005; Claffey et al., 2019a). Achieving high levels of DMI can be difficult in pasture-based systems in spring, due to inadequate spring grass availability (Claffey et al., 2019a), imposed grazing severity to ensure high quality grass in subsequent rotations (Ganche et al., 2013) and difficult grazing conditions (Kennedy et al., 2011) due to high levels of rainfall, all of which may contribute to limiting cows from achieving their potential production performance (Stockdale, 2004; Faverdin et al., 2011).

Meeting the early-lactation nutritional requirements of dairy cows is essential to achieve high levels of production and ensure good health and fertility (Rodney et al., 2018). Intake capacity (Wilkins, 2004; Faverdin et al.,

Received December 8, 2023.
Accepted April 12, 2024.
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The list of standard abbreviations for JDS is available at adsa.org/jds-abbreviations-24. Nonstandard abbreviations are available in the Notes.

2011) and DMI (Bargo et al., 2002; McEvoy et al., 2008) have been reported to have the largest effect on animal performance. Previous studies have reported high intakes in confinement systems (23.4 and 19.7 kg of DM/cow per day, respectively; Kolver and Muller, 1998; O'Neill et al., 2011); however, there is little research to date in pasture-based systems, particularly in early lactation as measuring DMI in pasture-based systems is more difficult than confinement systems (Coleman, 2005). Lewis et al. (2015) previously investigated early-lactation DMI using measured intake data from various studies in Moorepark that were carried out from 2007 to 2011 and reported that DMI starts at 8 to 10 kg of DM/cow per day after calving and increases by 1 kg of DM/cow each week until wk 8, when peak milk yield was achieved, and then increases by 0.5 kg of DM/cow per day until peak DMI is achieved on wk 12 of lactation. In pasture-based systems, cows typically experience peak milk yields at wk 8 of lactation (Lewis et al., 2015) due to the seasonality of grass growth as the physiological needs of the dairy cow are synchronized with pasture supply (Wood, 1972), whereas cows in indoor systems typically reach peak milk production between wk 4 and 8 of lactation, after which daily milk yields decline until the prepartum period (Keown et al., 1986). Measuring DMI during early lactation in a pasture-based system will lead to improved feeding management during early lactation and will allow for cows to achieve their potential milk production with reduced incidences of feed restriction.

Energy is the most limiting nutrient during early lactation (Bargo et al., 2002); however, animal performance can be increased with improved management and nutrition (Ingvartsen and Andersen, 2000). At the beginning of lactation, cows enter a state of negative energy balance (**NEB**; Collard et al., 2000) during which there is an increase in energy demand compared with the prepartum period (Ingvartsen and Andersen, 2000), as milk production increases rapidly (García and Holmes, 1999). Animal DMI is lower immediately postpartum compared with later in lactation due to reduced intake capacity (Mekuriaw, 2023), along with changes in reproductive status and metabolic changes to support the onset of lactation (Ingvartsen and Andersen, 2000). This difference in energy intake and energy output creates a NEB, which leads to increased concentrations of nonesterified fatty acids and fat mobilization, which can result in BW loss (Ingvartsen and Andersen, 2000). The severity and duration of the NEB is influenced by BCS at calving, DMI, milk production, and feed quality (Gross et al., 2011; Mekuriaw, 2023) and NEB can also be more pronounced in pasture-based systems (Claffey et al., 2019b), as cows may be restricted due to low spring grass availability (Claffey et al., 2019a) and unfavorable grazing conditions (Kennedy et al., 2011). Kolver and Muller (1998) reported that dairy cows in a pasture-based system required supplementation with high-energy feeds such as concentrates during early lactation to achieve their potential milk production. There is limited research that measures total DMI (**TDMI**) and energy balance during early lactation in pasture-based systems, and profiling energy requirement may be beneficial in reducing the severity of NEB. Cows that are well suited to the pasture-based system are highly efficient at converting feed to milk and are able to maintain high levels of pasture intake throughout lactation (Buckley et al., 2005). Previous studies have reported greater production efficiencies with Jersey × Holstein Friesian (**JeX**) cows compared with Holstein Friesian (**HF**) cows in pasture-based systems (Prendiville et al., 2009; O'Sullivan et al., 2019; McClearn et al., 2022).

The objective of the current study was to quantify individual TDMI during the first 12 wk of lactation to create an intake profile for dairy cows in pasture-based systems during early lactation, while maintaining high levels of herbage utilization, which is an important objective of pasture-based systems in Ireland and internationally, such as in New Zealand (Wilkinson et al., 2020). This study also aims to investigate animal performance, energy balance, and production efficiencies during early lactation. The hypothesis of the current experiment is (1) milk production and total DMI would increase with parity, (2) HF and JeX cows would have similar total DMI during early lactation, and (3) JeX cows would have greater MSol production and improved production efficiencies compared with HF cows.

MATERIALS AND METHODS

Experimental Site and Design

This experiment was conducted at the Teagasc Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork (52°7′3″N, 8°16′42″W; 49 m above sea level). A 2-yr (2021 and 2022) experiment was carried out to develop a profile of DMI and milk production during the first 12 wk of lactation (**WOL**). Eighty spring-calving dairy cows (60 multiparous and 20 primiparous) were randomized and placed into 1 of 2 grazing groups once they calved based on the previous year's milk production for multiparous cows and dam's first lactation for primiparous, breed (HF and JeX), parity, calving date (February 12 ± 17 d in yr 1 and February 18 ± 20 d in yr 2), economic breeding index (**EBI**; €184), BW (547 ± 69.9 kg) and BCS at calving (Table 1). Each year, cows were placed into 1 of 2 grazing groups (n = 40), and each grazing group had a farmlet of 15.3 ha with 23 paddocks per grazing group. Grazing began on February 1 in both years. During the experimental period cows

Table 1. Initial herd characteristics for the animals used in the experiment in yr 1 (2021) and yr 2 (2022)

Variable	Mean (2021)	SD (2021)	Mean (2022)	SD (2022)
Calving date	February 12	±17 d	February 18	±20 d
Breed	40[1]/40[2]	—	52[1]/28[2]	—
Lactation number	3.2	±1.98	2.9	±1.94
Daily milk yield (kg/cow)	20.1	±4.14	16.7	±3.36
Milk protein concentration (g/kg of milk)	37.0	±2.49	38.0	±2.34
Milk fat concentration (g/kg of milk)	50.4	±5.44	53.7	±6.07
Daily milk solids yield (kg/cow)	1.72	±0.351	1.52	±0.308
Pre-experimental BW (kg/cow)	598	±76.7	496	±62.0
Pre-experimental BCS	3.2	±0.28	3.1	±0.37

[1]Holstein Friesian.

[2]Jersey × Holstein Friesian.

were offered an average daily herbage allowance (**DHA**) to achieve a postgrazing sward height (**postGSH**) of 4 cm, to maintain high levels (>85%) of grass utilization, plus 3 kg of concentrate/cow per day fresh weight with 1.5 kg fed at the morning and 1.5 kg fed at the evening milking. Daily herbage allowance was calculated each day using measured pregrazing herbage mass (**preGHM**) to a target of 4 cm. Herbage allowance was adjusted daily based on the previous days postGSH as the DHA was increased when this was <4 cm to reduce restriction of DMI. In the current study, animals were allocated grass daily, and as such, TDMI may have been limited as animals were not offered ad lib allowances; however, this was kept to a minimum by adjusting the DHA when postGSH was below 4 cm (average postGSH = 4.02 cm).

Fresh pasture was offered after morning and evening milking and back fences were used to avoid re-grazing previous allocations. On-off grazing as described by Kennedy et al. (2011) was implemented for 24 d in yr 1 and 23 d in yr 2, and cows were fully housed for 4 d in yr 1 and 1 d in yr 2. Silage supplementation was also offered when necessary due to climatic conditions and spring grass availability. On average, cows were offered a total of 187.8 kg of DM silage/cow from wk 2 to wk 12 of lactation. A Keenan diet feeder (Keenan Holdings Limited, Borris, Co. Carlow, Ireland) was used to allocate fresh silage to the cows to ensure the silage was evenly distributed along the feed barrier. The feed face allowed 0.3 m of head space for each cow as recommended by Teagasc (Teagasc, 2016). A silage sample was taken each week when silage was offered to determine DM content, and this was used to calculate fresh weight to be fed using the following calculation: (number of cows × kg of DM offered)/DM %.

The soil type at the experimental site was a free-draining, acid brown soil with a sandy loam to loam texture. Soils had a pH of 6.8 (±0.2), P index of 3.8 (±0.4), and K index of 3.3 (±0.8; scale 1–4; 1 = deficient, 4 = no response to application of nutrient; Alexander et al., 2008). Daily rainfall (mm), air temperature (°C), and soil temperature to a depth of 100 mm (°C) were recorded daily at the experimental site. The swards mainly consisted of perennial ryegrass (**PRG**; *Lolium perenne* L; PRG >85%), whereas the remainder consisted of meadow grasses and white clover (*Poa annua*, *Festuca pratensis*, and *Trifolium repens* L. 'Chieftain').

Animal Measurements

Animals were milked twice each day throughout the experiment at 0700 h and 1500 h. Milk yields (kg/cow per day) were recorded each day at morning and evening milking for every cow (Dairymaster, Causeway, Co. Kerry, Ireland). Fat and protein contents were determined weekly by taking samples from one successive morning and evening milking before being analyzed using Milkoscan 203 (Foss Electric DK-3400, Hillerød, Denmark). Body weight and BCS were also measured weekly throughout the experimental period. Body weight was measured using an electronic portable weighing scale and Winweigh software package (both from Tru-test Limited, Auckland, New Zealand). Body condition score was recorded by an experienced independent observer using a scale ranging from 1 to 5, where 1 = emaciated and 5 = extremely fat, with 0.25 increments (Edmonson et al., 1989).

Individual TDMI (grass, silage, and concentrate) was measured biweekly on 6 occasions (wk 2, 4, 6, 8, 10, and 12 of the experiment) in each year of the study from February 1 until April 23 using the n-alkane technique as described by Mayes et al. (1986) and modified by Dillon and Stakelum (1989). A recent study (Wright et al., 2019) evaluating the n-alkane technique for estimate of individual DMI was reported to provide a very appropriate measure, with a Lin's concordance correlation of 0.69 for the C31/C32 pair. The cows were dosed before morning and evening milking for 11 d using a paper bullet (Carl Roth, GmbH, Karlesruhe, Germany) containing 500 mg of dotriacontane (C32, alkane). On the final 5 d of dosing (d 7–11) fecal samples were collected from each cow before morning and evening milking. Once fecal samples were collected, they were stored at −20°C, and at the end of each sampling period, these samples were thawed and bulked by cow (14.4 g/sample, 144 g/cow total). Bulked samples were dried at 60°C for 72 h and milled through a 1-mm sieve before being stored for analysis of alkane concentration. During d 6 to 10 of the sampling period, herbage samples representative of the next grazing allocation were collected. Two herbage samples per grazing group were taken each day using Gardena hand shears. When silage was included in the diet during intake measurements, silage samples were also collected each morning on d 6 to 10 before cows were allowed into the shed for silage. The herbage and silage samples were stored at −20°C, bowl chopped (Muller, typ MKT 204 Special, Saabrücken, Germany) and freeze-dried at −50°C for 72 h before being milled through a 1-mm sieve and stored for analysis of alkane concentration. Total DMI was estimated using the equation described by Mayes et al. (1986):

$$\text{DMI}(\text{kg}) = \frac{(\text{F}i/\text{F}j) \times \text{D}j}{\text{H}i - [(\text{F}i/\text{F}j) \times \text{H}j]},$$

where Fi is the concentration (mg/kg DM) of the C31 (odd number of carbon atoms) natural alkanes in feces, Fj is the concentration in feces of the C32 (even number of carbon atoms) from the dosed synthetic C32 alkane external marker, Hi is the concentration of C31 in herbage, Hj is the concentration of C32 in the herbage, and Dj is the daily dose of C32 (mg/d).

Energy Balance and Production Efficiencies

Energy balance for individual animals was calculated as the difference between estimated energy requirement and total energy intake. Energy expenditure was based on unité fouragère lait (**UFL**; feed units for milk) required for milk production, maintenance, growth (cow <40 mo), and BW change (Faverdin et al., 2007; INRA, 2017). Energy balance for individual animals was calculated as the difference between estimated energy requirements (UFL used for growth, maintenance, and milk production) and estimated total energy intake (UFL intake of grass, silage, and concentrates; INRA, 2017).

$$\text{UFL maintenance} = 0.41 \times \text{BW}^{0.75 \times 1.2}$$

$$\text{UFL growth} = 3.25 - 0.08^{\text{age(mo)}}$$

$$\text{UFL milk production} = \text{Milk yield} \times \left(\begin{matrix} 0.44 + \{0.0055 \times [\text{milk fat content}(\text{g/kg milk}) - 40]\} \\ + \{0.0033 \times [\text{milk protein content}(\text{g/kg milk}) - 31]\} \end{matrix}\right)$$

Energy intake was calculated based on TDMI measured using the n-alkane technique using the net energy system (Vermorel, 1989), where 1 UFL of energy is defined as the net energy content of 1 kg of standard barley for milk production, which is equivalent to 1,700 kcal. The UFL supply for grass, silage, and concentrate was calculated by multiplying the measured individual DMI for each feed by the UFL content of the feed (e.g., grass DMI × UFL content of grass). The UFL supply for each feed was added together to give the total UFL intake.

Total DMI (kg of DMI) per 100 kg of BW was calculated by dividing measured TDMI by kilograms BW at the time of intake measurement and then multiplied by 100 to calculate per 100 kg of BW. Milk solids (**MSol**) produced per 100 kg of BW was calculated by dividing daily average MSol production for each week by measured BW for that week and multiplying it by 100 to calculate per 100 kg of BW.

Sward Measurements

Before grazing, preGHM was measured in each paddock (>4 cm) using an Etesia mower (Etesia UK Ltd., Warwick, UK). Two 1.2 × 10 m strips were cut in each paddock, and a rising plate meter (Jenquip rising plate meter, New Zealand) was used to measure grass height before and after each strip was cut, which was used to calculate sward density. All of the mown herbage was collected and weighed, and a 300-g sample was collected, from which a 100-g subsample was taken. Dry matter was determined by drying a 100-g subsample at 90°C for 16 h. Pregrazing herbage mass was calculated using the following equation (O'Donovan et al., 2002):

$$\text{pregrazing herbage mass (kg DM/ha)} = \left(\frac{\text{weight(kg)}}{\text{area(length} \times 1.2)} \times 10{,}000\right) \times \frac{\text{DM \%}}{100}.$$

Sward density was then calculated using the following equation:

$$\text{sward density (kg DM/cm per ha)} = \frac{\text{herbage mass(kg of DM/ha)}}{\text{precutting height} - \text{postcutting height}}.$$

Pregrazing herbage mass was corrected to 4 cm using the following equation:

$$\text{Pregrazing herbage mass >4 cm (kg of DM/ha)} = [\text{pregrazing height (cm)} - 4] \times \text{sward density (kg of DM/cm/ha)}.$$

A rising plate meter (Jenquip Rising Plate Meter, New Zealand) was used to measure preGSH (>4 cm) before cows grazed each paddock. Forty measurements were taken diagonally across each allocation before grazing. The same measurement was taken each day after grazing to determine postGSH.

A 100-g sample was taken from the silage offered to the cows each week and dried at 90°C for 16 h to determine the DM of the silage. The DM content was then used to calculate the fresh weight allocation each week as described previously. A second 100-g sample was taken and dried at 40°C for 48 h before being milled through a 1-mm sieve and stored for analysis.

Wet chemistry was used to determine the chemical composition of the grazed herbage and silage offered to the cows throughout the experiment. Herbage samples were collected from each paddock before grazing and dried at 60°C for 48 h before being milled through a 1-mm sieve and stored for chemical analysis. Samples were bulked for each treatment by week and were subsequently analyzed for DM, ash, CP, NDF, ADF, and organic matter digestibility (**OMD**). Ash concentration was estimated by burning a subsample in a muffle furnace at 500°C for 12 h (method 942.05; AOAC International, 1995). Crude protein concentration was determined using an N-analyzer (Leco FP-428; Leco Australia Pty Ltd., Baulkham Hills, NSW, Australia). The NDF and ADF concentrations were determined using a fiber analyzer (method 973.18; AOAC International, 1995) based on the method described by Van Soest et al. (1991). Organic matter digestibility was determined in vitro with the neutral detergent cellulose method (Morgan et al., 1989; Fibertec Systems; Foss, Ballymount, Dublin, Ireland) and calculated with the equation as described by Garry et al. (2018). Silage samples were also bulked by week for both treatments, and analyzed using wet chemistry for DM, OMD, ADF, NDF, CP, and ash concentrations as described previously. The UFL content of grass, silage, and concentrates was based on chemical composition of the feedstuff. The chemical composition was used to calculate gross energy of the feedstuff and the metabolizable energy was calculated based on the digestible energy of the forage. The milk net energy is calculated by applying the efficiency of the metabolizable energy and gross energy, and finally, the energy content of the forage is expressed as feed units for milk (UFL) by dividing the milk net energy by 1,700 (Faverdin et al., 2011).

Statistical Analysis

Statistical analysis was carried out using SAS version 9.4 (SAS Institute Inc., Cary, NC). Total DMI, daily yield, weekly fat and protein content, MSol, and BW were analyzed from wk 1 to 12 of lactation using PROC MIXED in SAS. The week number was the repeated measure, with individual cow as subject and included as random effect. The EBI PTA for milk yield (kg) were used as covariates in the model. The model contained terms associated with production including breed, parity, WOL, year, week of experiment within year, and grazing group. Week of lactation by breed and by parity interactions were analyzed along with breed by parity interactions. All nonsignificant interactions were removed from the model. Data were analyzed using the following model:

$$Y_{hijklm} = \mu + B_h + P_i + Y_j + W_{k(j)} + L_l + G_m + (L_l \times P_i) + (L_l \times B_h) + (B_h \times P_i) + X_{hijklmn} + e_{hijklmn},$$

where Y_{hijklm} = the response of the animal m of breed h, in parity i, in year j, in week of experiment k and week of lactation l; μ = mean; B_h = breed (h = 1 or 2); P_i = parity (i = 1, 2, or 3); Y_j = year (l = 1 or 2); $W_{k(j)}$ = week of experiment within year (k = 1–19 in yr 1 or 2); L_l = week of lactation (l = wk 1–12); G_m = grazing group (m = 1 or 2); $L_l \times P_i$ = interaction between week of lactation and parity; $L_l \times B_h$ = interaction between week of lactation and breed; $B_h \times P_i$ = interaction between breed and parity; $X_{hijklmn}$ = milk production covariate; and $e_{hijklmn}$ = the residual error term.

RESULTS

Milk Production and Composition

Year had a significant effect on daily yield and MSol, which were greater in yr 1 (+1.6 and 0.12 kg/cow per day, respectively), and milk protein content, which was greater in yr 2 (+0.5 g/kg of milk). Week of lactation and parity had a significant effect on daily yield. First-parity animals had the lowest yield (19.6 ± 0.64 kg/cow per day), followed by second-parity animals (24.1 ± 0.61 kg/cow per day) and third-parity animals had the greatest daily yield (26.3 ± 0.45 kg/cow per day). There was a significant interaction present between parity and breed for daily milk yield, with the JeX animals having the greatest yield among the first- and third-parity animals, whereas HF had the greatest yield for second-parity animals. There was also a significant interaction between WOL and parity; parity 2 and 3 animals were the same for wk 1 and 2 of lactation, whereas third-parity animals had a greater daily yield from wk 3 of lactation onward (Figure 1).

Week of lactation, parity, and breed had a significant effect on MSol production. First-parity animals had the lowest MSol (1.65 ± 0.065 kg/cow per day), followed by second-parity animals (2.07 ± 0.06 kg/cow per day), and third-parity animals had the greatest (2.25 ± 0.044 kg/cow per day). Holstein Friesian animals had signifi-

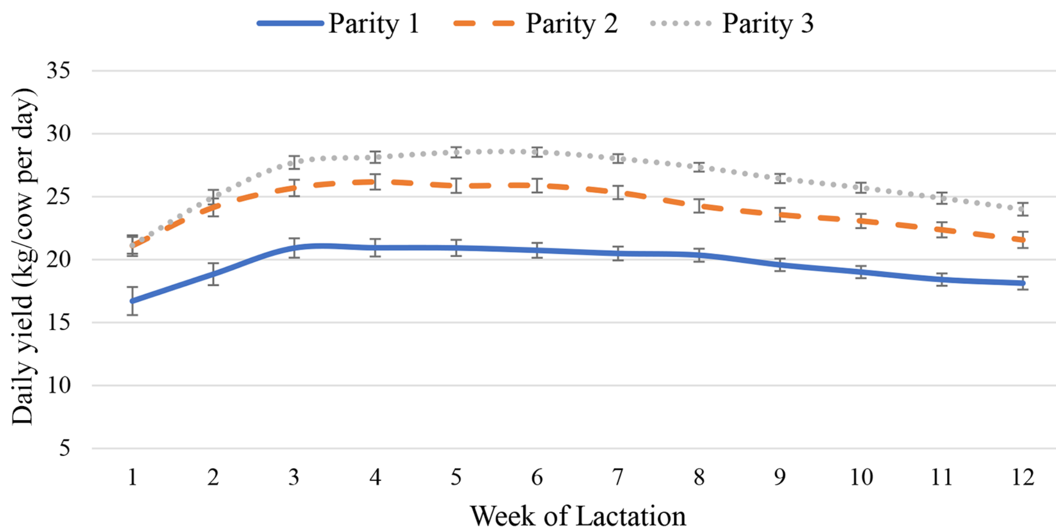

Figure 1. Daily milk yield for first-, second-, and third-parity animals in a spring-calving pasture-based system from wk 1 to wk 12 of lactation. Error bars represent SE.

cantly lower MSol (1.95 ± 0.052 kg/cow per day) compared with JeX (2.03 ± 0.052 kg/cow per day). There was a significant interaction between WOL and parity for MSol, whereby second- and third-parity animals had the same MSol production for wk 1 and 2 of lactation, and third-parity animals were significantly greater thereafter (+0.2 kg/cow per day; Figure 2). There was also a significant interaction between WOL and breed for MSol as all animals were the same for wk 1 to 3 of lactation and JeX were greater from wk 4 of lactation (+0.12 kg/cow per day).

There was a significant interaction between WOL and parity for milk protein content (Table 2), as parity 2 animals had a significantly greater milk protein content (35.2 ± 0.38 g/kg of milk) for wk 9 to 12 of lactation compared with parity 1 and 3 animals (34.3 ± 0.31 g/kg of milk). Milk protein content was significantly affected by WOL. There was a significant interaction between WOL and breed for milk fat content, as JeX had a greater milk fat content (49.5 ± 0.84 g/kg of milk) for wk 9 to 12 of lactation compared with HF (47.2 ± 1.04 g/kg of milk). Week of lactation also had a significant effect on

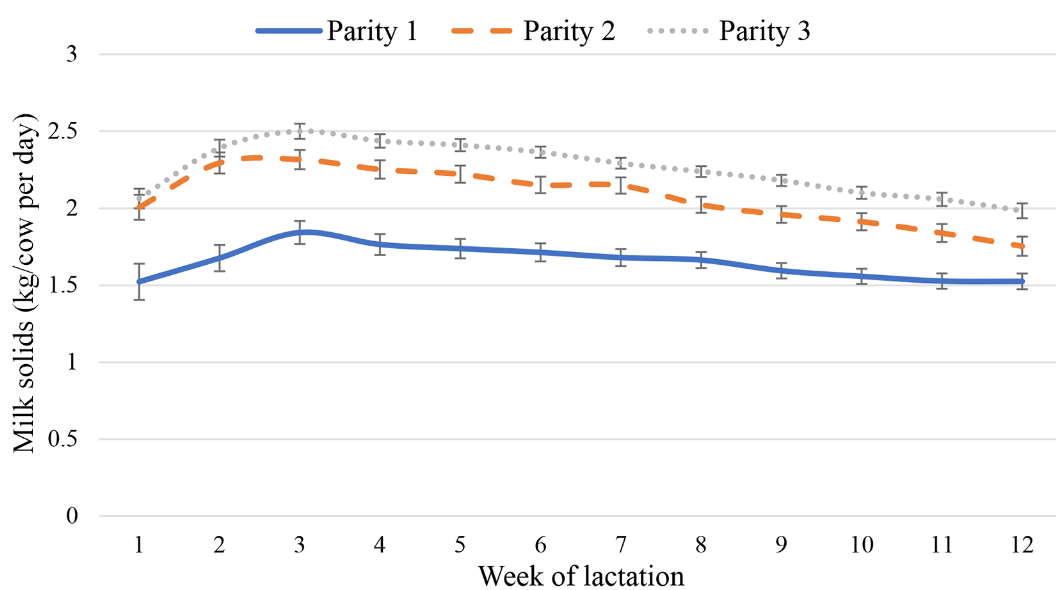

Figure 2. Milk solids production for first-, second-, and third-parity dairy cows in a spring-calving pasture-based system from wk 1 to wk 12 of lactation. Error bars represent SE.

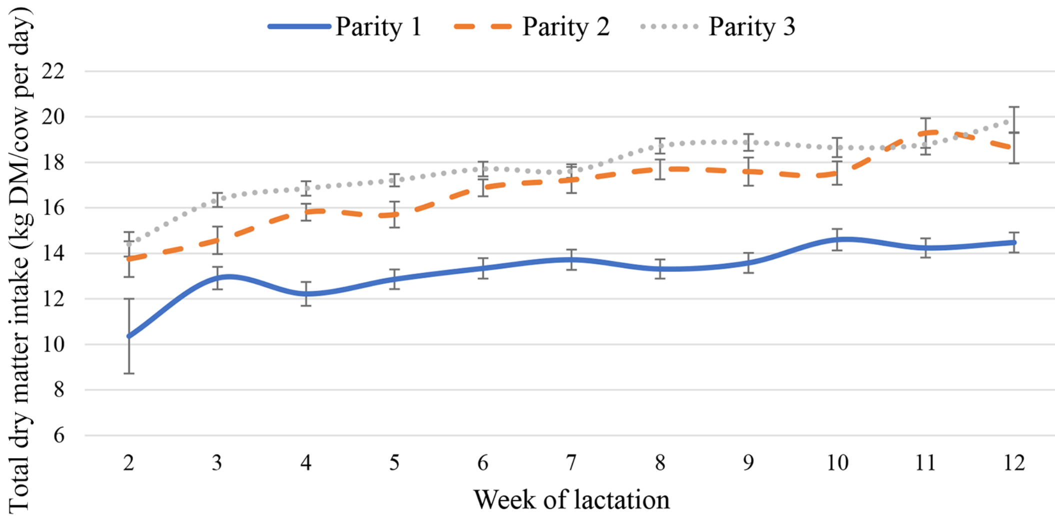

Figure 3. Total DMI consisting of grazed grass, grass silage, and concentrate of first-, second-, and third-parity dairy cows in a spring-calving pasture-based system from wk 2 to wk 12 of lactation measured using the n-alkane technique. Error bars represent SE.

milk fat concentration. Breed and parity had no effect on milk protein and fat concentrations.

Total DMI

Breed did not have an effect on TDMI; however, WOL and parity had an effect ($P < 0.05$) on TDMI (Figure 3). Average TDMI was lowest for first-parity animals (13.2 ± 0.56 kg of DM/cow per day) followed by second-parity animals (16.8 ± 0.56 kg of DM/cow per day) and greatest for third-parity animals (17.7 ± 0.38 kg of DM/cow per day; Table 2). On average, TDMI increased by 0.48 kg/cow per week from wk 2 to 12 of lactation. There was a significant interaction between WOL and parity for TDMI as second- and third-parity animals were the same for wk 2, 7, 11, and 12 and had significantly different TDMI for every other week (Figure 3).

BW and BCS

Week of lactation and parity had a significant effect on BW. Third-parity animals had the greatest BW (526 ± 7.3 kg) compared with first- and second-parity animals (488 and 505 ± 9.4 kg, respectively). There was a significant interaction between WOL and parity for BW as all animals had the same BW for wk 1, 10, 11, and 12, and third-parity animals had a greater BW compared with first and second parity for all other weeks (Figure

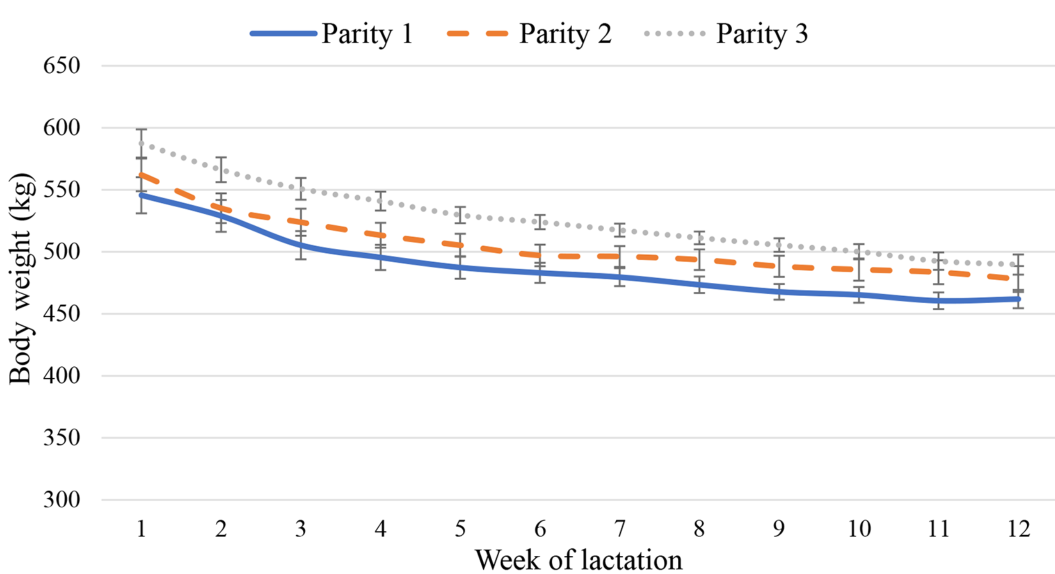

Figure 4. Body weight for first-, second-, and third-parity dairy cows from wk 1 to wk 12 of lactation. Error bars represent SE.

4). Body condition score was also significantly affected by WOL and parity (data not presented). Second-parity animals had significantly lower BCS (3.05 ± 0.03) compared with first- and third-parity animals (3.19 and 3.14 ± 0.03, respectively). Breed had no effect on BW or BCS.

Energy Balance and Production Efficiencies

Year had a significant effect on UFL supply and UFL requirement, both of which were greater in yr 1 (+0.7 and +0.9 UFL, respectively). Week of lactation and parity also had a significant effect on UFL requirement and UFL supply. The UFL requirement was greatest for third-parity animals (19.0 ± 0.17 UFL/cow per day), followed by second parity (17.8 ± 0.26 UFL/cow per day) and first-parity animals had the lowest UFL requirement (15.9 ± 0.28 UFL/cow per day). The UFL supply followed the same trend with 16.4, 15.4, and 12.0 ± 0.25 UFL/cow per day for third-, second-, and first-parity animals, respectively. The UFL balance (difference between UFL requirement and UFL supply) was significantly affected by WOL and parity (Figure 5). First-parity animals had a significantly greater NEB (−3.2 ± 0.27 UFL) compared with second- and third-parity animals (−2.3 ± 0.24 UFL) up to wk 12 of lactation. For the 3 parities, energy balance increased week by week. First-parity animals also remained in a NEB for the first 12 wk of lactation, whereas second- and third-parity animals experienced NEB until wk 10 of lactation.

Week of lactation, parity, and breed all had a significant effect on TDMI/100 kg of BW. First-parity animals had significantly lower TDMI/100 kg of BW (3.0 ± 0.12 kg of DM/100 kg of BW) compared with second- and third-parity animals (3.5 and 3.4 ± 0.10 kg of DM/100 kg of BW, respectively). Holstein Friesian animals had a lower TDMI/100 kg of BW compared with JeX (3.2 and 3.4 ± 0.09 kg of DM/100 kg of BW, respectively; Figure 6). There was a significant interaction between WOL and parity for TDMI/100 kg of BW, which was the same for all animals during wk 2 and 3 of lactation and first-parity animals were significantly lower than second- and third-parity animals thereafter (data not shown).

Year had a significant effect on kg of MSol/100 kg of BW, which was greater in yr 1 compared with yr 2 (0.41 and 0.39 ± 0.007 kg of MSol/100 kg of BW, respectively). Week of lactation, parity, and breed all had a significant effect on kg of MSol/100 kg of BW. First-parity animals had significantly lower kg of MSol/100 kg of BW (0.36 ± 0.013 kg of MSol/kg of BW) compared with second- and third-parity animals (0.42 and 0.43 ± 0.011 kg of MSol/100 kg of BW, respectively). The JeX animals had greater MSol/100 kg of BW (0.41 ± 0.009 kg of MSol/100 kg of BW) compared with HF (0.39 ± 0.011 kg of MSol/100 kg of BW; Figure 7). There was a

Table 2. The effect of parity and breed on daily milk yield, protein, and fat content, milk solids, total DMI, and BW from wk 1 to wk 12 of lactation in first second- and third-parity Holstein Friesian and Jersey× Holstein Friesian animals

Item	Holstein Friesian				Jersey × Holstein Friesian				*P*-value[1]		
	First parity	Second parity	Third parity	SE	First parity	Second parity	Third parity	SE	Parity	Breed	Parity × breed
Daily milk yield (kg/cow per d)	18.4[a]	24.3[c]	26.1[d]	0.59	20.7[b]	23.8[c]	26.5[d]	0.47	0.001	NS	0.025
Protein concentration (g/kg)	34.6	35.2	34.6	0.36	34.6	35.2	35.5	0.29	NS	NS	NS
Fat concentration (g/kg)	52.7	49.9	50.2	1.14	51.2	53.1	51.9	0.91	NS	NS	NS
Daily milk solids (kg/cow per d)	1.59[a]	2.06[b]	2.20[bc]	0.056	1.71[a]	2.09[b]	2.30[c]	0.044	0.001	0.03	NS
Grass DMI (kg of DM/cow per d)	8.2[a]	11.6[bc]	11.4[b]	0.34	8.4[a]	11.1[b]	12.1[c]	0.26	0.001	NS	NS
Silage DMI (kg of DM/cow per d)	1.8[a]	2.3[ab]	3.0[c]	0.27	1.8[a]	2.7[bc]	3.0[c]	0.20	0.001	NS	NS
Concentrate (kg of DM/cow per d)	3.1	3.0	3.0	0.05	3.1	3.0	3.0	0.04	NS	NS	NS
Total DMI (kg of DM/cow per d)	13.1[a]	16.8[b]	17.3[b]	0.38	13.4[b]	16.7[b]	18.1[c]	0.29	0.001	NS	NS

[a–d]Means within a row with different superscripts are significantly different ($P < 0.05$).

[1]NS = $P > 0.05$.

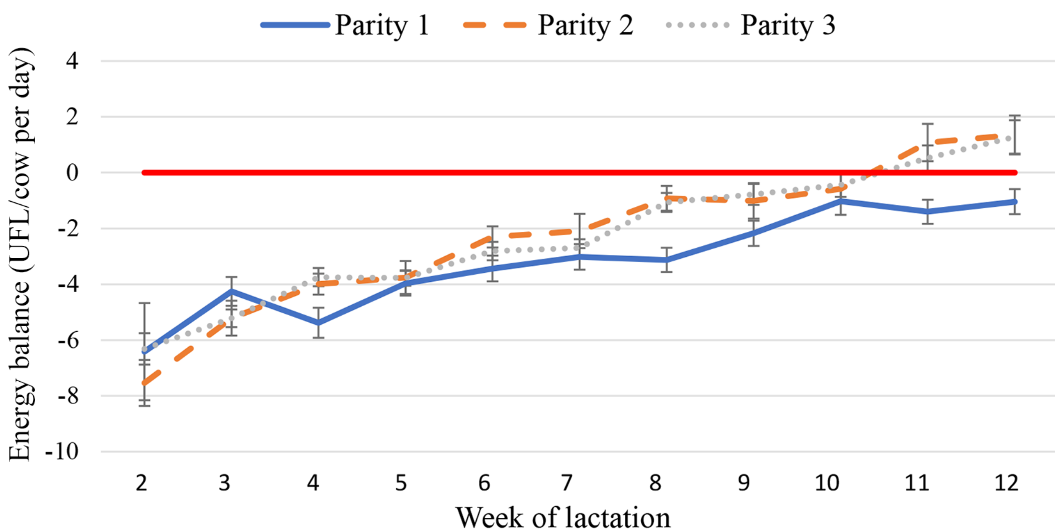

Figure 5. Energy balance (UFL/cow per day) for first-, second-, and third-parity dairy cows from wk 2 to wk 12 of lactation measured as the difference between energy requirement based on UFL needed for milk production, maintenance, and growth (animals <40 mo) and energy intake based on DMI of grazed grass, grass silage, and concentrate and the energy content of the feeds. Values below the red line indicate animals in negative energy balance. Error bars represent SE.

significant interaction between WOL and parity as first-parity animals were lower than second- and third-parity animals. There was also an interaction between WOL and breed (Figure 7) as the JeX animals had a significantly greater kg of MSol/100 kg of BW (0.42 ± 0.008 kg of MSol/100 kg of BW) compared with HF (0.38 ± 0.010 kg of MSol/100 kg of BW) from wk 4 until wk 12 of lactation.

DISCUSSION

Increasing productivity on pasture-based dairy farms depends on high pasture growth, sward quality and herbage utilization while also ensuring cows have adequate grass DMI (Delaby et al., 2018), which will reduce the severity of NEB that dairy cow's experience postpartum (Claffey et al., 2019b). There are limited studies to date

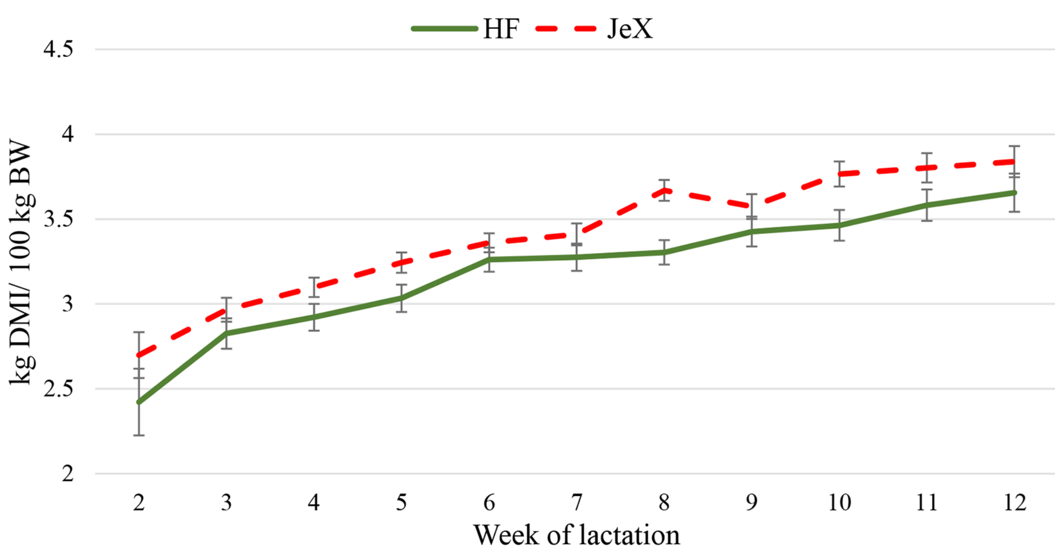

Figure 6. Total DMI (kg)/100 kg of BW for Holstein Friesian (HF) and Jersey × Holstein Friesian (JeX) dairy cows from wk 2 to wk 12 of lactation calculated using individual DMI measured using the n-alkane technique and the measured BW each week. Error bars represent SE.

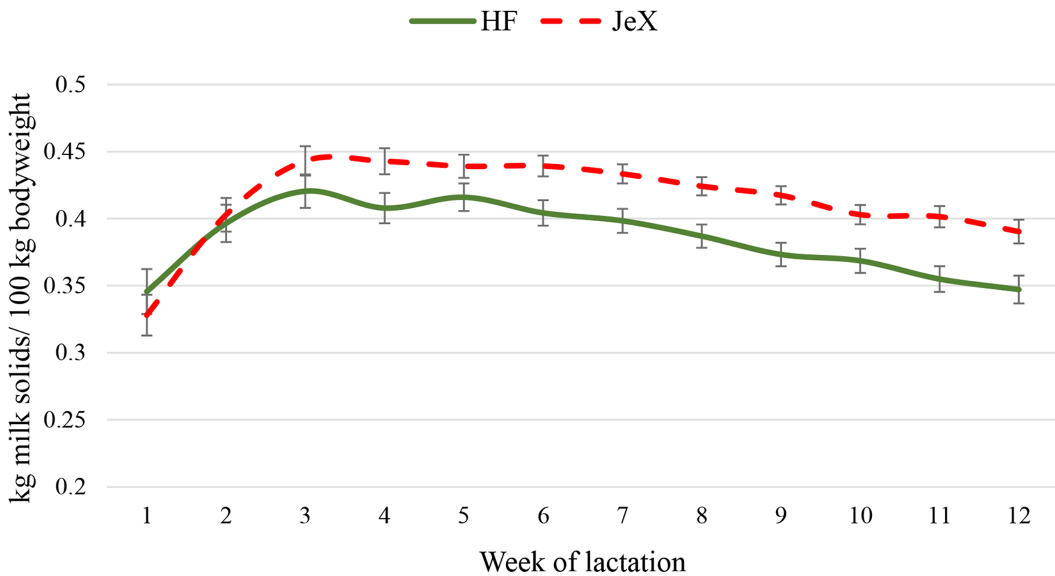

Figure 7. Kilograms of milk solids produced/100 kg of BW for Holstein Friesian (HF) and Jersey × Holstein Friesian (JeX) dairy cows from wk 1 to wk 12 of lactation calculated using milk solids production and the measured BW each week. Error bars represent SE.

which regularly measure early-lactation DMI as intake measurements can be more difficult in pasture-based dairy systems (Coleman, 2005); however, more recently Wright et al. (2019) reported that the n-alkane technique provided an accurate measure of TDMI. The objective of the current study was to measure and profile early-lactation DMI and energy balance during the first 12 wk of lactation in a pasture-based system while ensuring high levels of herbage utilization.

The current study measured an average daily TDMI across the herd (with 27% primiparous cows) of 13.2 kg of DM/cow per day on wk 2 of lactation, and increased by 38% to 17.7 kg of DM/cow per day on wk 12 of lactation. On average, the weekly increase in TDMI was 0.48 kg of DM/cow per week from wk 2 to 12 of lactation. This increase in TDMI was greater from wk 2 to 6 of lactation at 0.8 kg of DM/cow per week compared with wk 7 to 12 of lactation when DMI increased by 0.3 kg of DM/cow per week. The rate of increase across parity was not the same, with first-parity animals increasing by an average of 0.41 kg of DM/cow per week compared with the second- and third-parity animals, which increased by an average of 0.49 and 0.55 kg of DM/cow per week, respectively, similar to Marquardt et al. (1977) and McClearn et al. (2022). Early-lactation TDMI in the current study started higher than previously reported by Lewis et al. (2015) (+3.2 kg of DM/cow per week) and also increased at a slower rate, as Lewis et al. (2015) reported DMI increasing by 1 kg/cow/week; however, Lewis et al. (2015) reported a similar effect of parity on DMI. Genetic improvements over the last number of years and greater milk production potential of dairy cows (Berry et al., 2016; INRA, 2018) could be a reason for greater TDMI reported in the current study compared with Lewis et al. (2015). It is possible that early-lactation TDMI could also be greater than reported in the current study if cows were offered ad libitum grass and silage; however, a key objective of this study was to maintain herbage utilization, as is common in pasture-based systems both in Ireland and internationally. In the current study, second- and third-parity animal's TDMI was 22% and 26% greater than first-parity animals similar to the findings of McClearn et al. (2022). The increase in TDMI for multiparous cows compared with primiparous cows may be partially due to the greater BW and larger rumen capacity of multiparous cows (Bines, 1976; Beauchemin et al., 2002; Reshalaitihan et al., 2020); however, these studies are from indoor systems, and there is limited data on this in grazing systems to date. In the current study, TDMI/100 kg of BW was the same for second- (3.48 kg of DM/100 kg of BW) and third-parity animals (3.44 kg of DM/100 kg of BW); however, first-parity animals were significantly lower (2.98 kg of DM/100 kg of BW) due to the lower BW (−28 kg/cow) of primiparous animals. The physiological state of an animal can reduce intake capacity, with young, fat, and pregnant animals having a lower intake capacity compared with older, thinner, and nonpregnant animals (Bines, 1976; Broster and Broster, 1998). Reshalaitihan et al. (2020) reported that primiparous animals had reduced serum total protein TP concentrations and higher serum nonesterified fatty acid concentrations before calving compared with multiparous animals, which can reduce intake before calving and, therefore, may have indirectly reduced DMI after parturition. Similar to the findings of McClearn et al. (2022), Vance et al. (2012), and Prendiville et al. (2010), breed did not influence TDMI or the rate of DMI increase across early lactation, which may be as a result of similar daily milk yield and BW for the 2 breeds throughout the current experiment.

The current study reported that peak TDMI was reached on wk 11 of lactation (17.9 kg of DM/cow per day), 6 wk after peak milk production was achieved on wk 5 of lactation (25.1 kg/cow per day) and 8 wk after peak MSol production was reached on wk 3 of lactation (2.22 kg/cow per day). Daily milk yield increased by 1.36 kg/cow per week from wk 1 until wk 5 of lactation and decreased by 0.55 kg/cow per week from wk 5 until wk 12 of lactation as milk yield decreases after peak yield is achieved (García and Holmes, 2001). Previous studies (Knight and Wilde, 1987; Boutinaud et al., 2004; Gross and Bruckmaier, 2019) have reported that the increase in milk production in early lactation is caused by the rate of cell differentiation, which increases the number of milk secreting cells, and after peak yield is achieved, a decline in milk yield is attributed to the rate of cell apoptosis. The number of milk secretory cells declines by 17% between d 90 and 240 of lactation, which leads to a 23% reduction in milk production (Boutinaud et al., 2004), similar to the current study as milk yield declined by 15% from d 35 to d 84. Similar to previous studies (Horan et al., 2005; Lee and Kim, 2006; McClearn et al., 2022) daily milk yield increased with parity. Second- and third-parity animals in the current study had 19% and 25% greater daily milk yields compared with first-parity animals, respectively. This difference in yield can be accounted for due to the lower TDMI (McClearn et al., 2022), lower peak milk production, which leads to a lower cumulative milk production (Wood, 1972) and the effect of energy partitioned for growth in primiparous animals (Coffey et al., 2006; Wathes et al., 2007). The mammary gland of multiparous cows is also more metabolically active and has a greater density of secretory cells compared with primiparous cows, particularly in early lactation, both of which are a cause of the differences in milk production seen among parities in early lactation (Miller et al., 2006).

Previous studies have reported significantly greater milk yields of up to 1.4 kg/cow per day in HF cows compared with JeX cows (Prendiville et al., 2011; Coffey et al., 2017; McClearn et al., 2022); however, there was no difference between HF and JeX cows in the current study (22.9 and 23.7 kg/cow per day, respectively). The greater MSol production (+0.08 kg of MSol/cow per day) from JeX cows in the current experiment is consistent with previous studies (Prendiville et al., 2009; Vance et al., 2012), which is a result of the higher milk composition (+2.2 and +0.42 g/kg milk fat and protein concentration, respectively) associated with the Jersey breed (Prendiville et al., 2011; Vance et al., 2012). The study reiterates the ability of JeX cows to produce similar milk yields to HF cows while producing significantly higher MSol.

It has been widely reported that dairy cow BW decreases during early lactation (Gross et al., 2011; Poncheki et al., 2015; Coffey et al., 2017), and this loss in BW can be more pronounced in pasture-based systems due to lower DMI at grazing (Bargo et al., 2002; Vance et al., 2012). Gross et al. (2011) reported BW decreased from calving until wk 7 of lactation and remained similar from wk 7 to 12. In the current study BW loss was greatest from wk 1 to wk 4 of lactation at −14.4 kg/cow per week and this decreased to −4.4 kg/cow per week from wk 5 to wk 12 of lactation. This decrease in BW loss after wk 4 of lactation is a result of greater TDMI as WOL increases and reductions in energy partitioned to milk production as production reduced after peak yield on wk 5 of lactation. Body weight was greater for animals as parity increased, which is similar to previous studies (Horan et al., 2005; Roche et al., 2007; McClearn et al. 2022). Greater BW is associated with higher milk yield (Macdonald et al., 2005; Handcock et al., 2019), which is consistent with the results of the current study, as BW had a positive linear relationship with daily milk yield ($R^2 = 0.74$). This is similar to the findings of Kul et al. (2021), who reported a moderate to high positive correlation between BW and milk yield ranging from 0.45 to 0.59.

Similar to Friggens et al. (2007) cows experienced the greatest degree of NEB on wk 2 of lactation as TDMI is lowest at this time. The rate of change for energy balance was lower for first-parity animals (+0.54 UFL/cow per week) compared with second- and third-parity animals (+0.89 and 0.76 UFL/cow per week); therefore, second- and third-parity animals spent less time in a NEB at 10 wk compared with first-parity animals that were in NEB for the duration of the 12-wk study. Similar to Grummer and Rastani (2003), there was no correlation between energy balance and daily milk yield in the current study; however, there was a strong positive correlation between energy balance and TDMI ($R^2 = 0.84$) and also between energy balance and energy intake ($R^2 = 0.84$). The relationship between energy balance and TDMI may explain the longer period of NEB for first-parity animals, as their TDMI was significantly lower compared with second- and third-parity animals (−3.7 and 4.2 kg of DM/cow, respectively). This contrasts with the findings of Friggens et al. (2007), who reported that first-parity animals mobilized less body reserves compared with second- and third-parity animals, resulting in first-parity animals spending a shorter duration in NEB. The differences between these 2 studies may be a result of different diets, as cows were offered a normal or high-energy TMR diet in the study by Friggens et al. (2007). The subsequent effects of grazing behavior in the current study may have caused differences as first-parity animals take smaller bites and spend longer grazing compared with multiparous cows (Iqbal et al., 2022), which may increase NEB for first-parity animals if smaller grazing areas are offered during spring. The different breeds used may also have caused the difference as Friggens et al. (2007) used Danish Red, Danish Holstein, and Jersey cows. Negative energy balance was not calculated after wk 12 of lactation in the current study; therefore, it is possible that first-parity animals remained in a state of NEB for longer than 12 wk.

The pasture-based system requires a cow that can achieve high levels of intake and milk production per unit of BW and also an animal that can meet most of its nutritional requirements from grazed grass through high levels of DMI relative to their genetic potential for milk production (Buckley et al., 2005). The current study compared the efficiency of HF and JeX animals during early lactation using TDMI/100 kg of BW and MSol/100 kg of BW, both of which were greater for JeX animals, which highlights the suitability of the JeX breed to pasture-based systems with increased production efficiency with greater intakes and MSol/100 kg of BW. The JeX cows in the current study had a greater TDMI/100 kg of BW compared with the HF cows (+5.9%), which is similar to the findings of McClearn et al. (2022) and Coffey et al. (2017). Prendiville et al. (2009) and Beecher et al., (2014) reported that JeX cows had a higher intake capacity, due to a greater gastrointestinal tract weight and reticulorumen compared with HF cows. Coffey et al. (2017) reported HF cows utilize a greater proportion of energy for maintenance, and therefore, have a lower feed conversion efficiency compared with JeX cows; however, in the current study there was no difference in UFL required for maintenance between HF and JeX cows. The JeX cows did have a higher UFL requirement for milk production compared with HF cows (12.2 and 11.6 UFL, respectively), which may have allowed for the JeX cows to have a greater MSol/100 kg of BW as they partitioned more energy toward milk production compared with the HF cows, which was achievable due to greater TDMI/100 kg of BW.

CONCLUSIONS

The intake profile quantified in the current study illustrates high TDMI from the beginning of lactation and a rapid increase in intakes with +0.8 kg of DM/cow per week until wk 6 of lactation and +0.3 kg of DM/cow per week from wk 7 to 12 of lactation. While both the HF and JeX cows had similar TDMI and daily milk yield, the JeX cows had greater MSol production compared with the HF cows. The greater production efficiency of the JeX cows allowed for greater TDMI/100 kg of BW and greater MSol/100 kg of BW. Improving efficiency in pasture-based systems during early lactation is difficult as maintaining high pasture intakes can be a challenge with reduced growth and difficult grazing conditions. The results of the current study allow for a better understanding of the intake profile and energy requirements of dairy cows during early lactation.

NOTES

This experiment was funded by Irish Dairy Levy Funding administered by Dairy Research Ireland (Cork, Ireland) and the Teagasc Walsh Scholarship Programme (Carlow, Ireland). The authors thank J. P. Murphy, M. Liddane, A. McGrath, P. O'Connor, and C. Fleming for their technical assistance, and all the staff of Moorepark research farm for their care and management of the animals and assistance with measurements throughout the experiment. The Health Products Regulatory Authority (HPRA), Ireland, provided authorization (AE19132/P106) as required for the protection of animals used for scientific purposes in European Union legislation (Directive 2010/63/EU). Ethical approval was also received from the Teagasc Animals Ethics Committee. The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: DHA = daily herbage allowance; EBI = economic breeding index; HF = Holstein Friesian; JeX = Jersey × Holstein Friesian; NEB = negative energy balance; OMD = organic matter digestibility; PRG = perennial ryegrass; TDMI = total DMI; UFL = unité fouragère lait; WOL = weeks of lactation.

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