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Nutritional and non-nutritional factors associated with bulk tank milk fat concentration in Irish commercial spring-calving grazing dairy herds

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ABSTRACT

The objectives of this experiment were (1) to identify associations between nutritional and non-nutritional factors and bulk tank milk fat concentration and (2) to develop a multivariable model capable of predicting herd-level milk fat concentration for Irish commercial spring-calving grazing dairy herds. An observational experiment comprising 25 commercial spring-calving dairy herds was conducted over a 2-yr period. Farms were visited 10 times per year, which coincided with each grazing rotation. During each visit, grassland measurements and pasture samples were collected from the next 2 paddocks to be grazed. Concentrate, silage, and other supplementary ingredients were sampled if included as part of the diet at each visit. Bulk tank milk samples were collected, along with data on pasture management, herd management, and herd genetic characteristics. Using the data from 12 of the 25 herds (i.e., model development data set), univariate analysis was performed to identify the relationships between each explanatory variable and milk fat concentration. Variables with a univariate analysis of $P < 0.2$ were included in a multivariable linear regression model, and backward stepwise elimination was performed until the remaining variables had $P < 0.05$ and the most parsimonious model was achieved. The predictive performance of the multivariable linear regression model was evaluated using the data from the remaining 13 herds (i.e., model evaluation data set). Across the whole data set, average bulk tank milk fat concentration was 4.54% ± 0.50%, with a range of 3.56% to 6.09%. The lowest average milk fat concentrations were observed during grazing rotations 3 and 4, coinciding with the late spring and early summer periods (i.e., May to early June), with the highest average milk fat concentration observed during grazing rotation 10. The average concentrations of de novo, mixed, and preformed milk fatty acids were 27.9 ± 2.0, 32.5 ± 1.6, and 37.5 ± 3.3 g/100 g of fat, respectively. Although several univariate relationships were identified, backward stepwise elimination identified a multivariable linear regression model with grazing rotation and the herd's milk fat concentration PTA as factors associated with bulk tank milk fat concentration. For the model evaluation data set, an initial multivariable linear regression model predicted bulk tank milk fat concentration with an R^2 of 0.73 and a root mean square error (RMSE) of 0.23%. The slope between observed and predicted bulk tank milk fat concentration was 1.15 (SE = 0.06), with an average bias of 0.05% and a relative prediction error (RPE) of 1.09. When a final model was evaluated, which was developed for all 10 rotations, the model predicted bulk tank milk fat concentration with an R^2 of 0.79 and a RMSE of 0.23%. The slope between observed and predicted bulk tank milk fat concentrations was 1.09 (SE = 0.04) with an average bias of 0.05% and an RPE of 1.06. Although the association between grazing rotation and bulk tank milk fat concentration is likely multifactorial, involving many nutritional and non-nutritional factors, the positive relationship between milk fat concentration PTA and milk fat concentration highlights the important role of genetics on milk fat production in pasture-based systems.

Key words: dairy cow, milk fat production, grazing, seasonality

INTRODUCTION

Milk fat is a key determinant of the economic value of milk with fluctuations in milk fat concentration, having both economic and environmental implications. In pasture-based systems, large variability in milk fat concentration occurs across the grazing season in both the

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northern (Carty et al., 2017) and southern (Calvache et al., 2009) hemispheres, with the lowest concentrations typically occurring during the summer period (Salfer et al., 2019). In Ireland, a consistent reduction in milk fat concentration occurs from early spring (i.e., February/March) to early summer (i.e., May/June), with an absolute reduction of 0.44% observed during 2023 (CSO, 2024). Due to the strong negative relationship between milk yield and milk fat concentration (Silvestre et al., 2009), the reduction has been linked to the herd's stage of lactation in spring-calving pasture-based systems. However, Carty et al. (2017) observed that the greatest reduction in milk fat concentration occurred in the month of May, irrespective of stage of lactation or DIM, suggesting that time of year could have a greater influence on milk fat concentration. Several other factors have been linked to the reduction in milk fat concentration, such as pasture management, pasture nutritive value, and herd genetic merit (Carty et al., 2017; Neville et al., 2023).

Quantifying diet-induced milk fat depression (**MFD**) has been approached in several different ways; for example, the reduction in bulk tank milk fat concentration of greater than 0.4% within a 10-d period (Calus et al., 2005). In temperate pasture-based systems, the grazing of swards with low herbage mass has been implicated in the onset of diet-induced MFD (Carty et al., 2017). Such swards have been suggested to contain high concentrations of fatty acids (**FA**) and low concentrations of NDF (Rivero and Anrique, 2015) during the period of high risk for reduced milk fat concentration. Heffernan et al. (2024) observed no effect of herbage mass on pasture NDF concentration or NDF digestibility during the high-risk period. In addition, sufficient NDF concentrations to maintain milk fat concentration (>35%; Kolver, 2000) were observed across the experiment. Although greater FA concentrations were observed in swards with low herbage mass compared with those with medium and high herbage mass, no increases in FA concentrations were detected across the high-risk period (Heffernan et al., 2024). It is possible that milk fat concentration is reduced due to an interaction between pasture nutritive value and concentrate supplementation (Bargo et al., 2003). However, the effect of concentrate supplementation on milk fat concentration has not been consistent, with concentrate supplementation level and concentrate type likely involved in the inconsistent responses (Kennedy et al., 2008; Rugoho et al., 2017; Heffernan et al., 2025a).

Several experiments have demonstrated the effect of genetic merit on the milk fat concentration of grazing dairy cows (O'Sullivan et al., 2019; Lahart et al., 2024). Calus et al. (2005) identified susceptibility to MFD as a possible breeding trait and estimated the heritability to be 4% and 5% for MFD magnitude and duration, respectively. Although breeding strategies to improve resistance to MFD are a longer-term solution, a greater understanding of the nutritional and non-nutritional factors associated with milk fat concentration at farm level is required. This knowledge could enable the development of effective management strategies to either alleviate the occurrence or reduce the severity of MFD in pasture-based systems. Therefore, we designed an observational experiment to test the hypothesis that commercial farm factors such as pasture management, pasture nutritive value, and herd genetic merit would be associated with bulk tank milk fat concentration. Overall, our objectives were (1) to identify associations between nutritional and non-nutritional factors and bulk tank milk fat concentration and (2) to develop a multivariable model capable of predicting herd-level milk fat concentration for commercial spring-calving grazing dairy herds.

MATERIALS AND METHODS

A total of 25 spring-calving dairy herds were selected based on farm system, soil type, region, and ability to undertake grassland management practices and enrolled into an observational experiment to identify associations between nutritional and non-nutritional factors and bulk tank milk fat concentration. The herds were spread across a geographical area that included 6 counties of Ireland: Cork (n = 9), Limerick (n = 6), Tipperary (n = 4), Kerry (n = 3), Laois (n = 2), and Kilkenny (n = 1). When identifying herds to enroll, farm management practices that promoted grassland utilization via rotational paddock grazing were prioritized, with all herds previously obtaining 10 grazing rotations in the previous year. As inclusion criteria, all herds were required to actively use PastureBase Ireland (**PBI**; Hanrahan et al., 2017) as a method to record and manage pasture, and to have completed a minimum of 20 farm pasture cover estimations during the previous growing season. Herds were visited 10 times a year during the lactation period (March to November) for 2 consecutive years (2021 and 2022), with each time point aligning with a different grazing rotation. Data related to grazing management, feed supplementation, and milk production were recorded.

Pasture Measurements

At each sampling time point, pasture measurements were taken on 2 paddocks, which were identified by the farmer as the next to be grazed in the rotational sequence. Pre-grazing herbage mass (>4 cm) within each paddock was determined by using the average of 2 quadrat cuts (0.25 × 0.25m) harvested using a Gardena hand shears (Accu 60, Gardena International GmbH, Germany). Pre- and post-cutting compressed sward heights were measured at each quadrat cut using a rising plate meter (diameter 355 mm, 3.2 kg/m^2; Jenquip, Feilding, New Zealand). Each quadrat-cut sample was weighed, and a 100-g subsample was dried at 90°C for 16 h for DM determination. An additional subsample from both quadrat cuts was composited to create a singular paddock sample, which was snap frozen and stored on dry ice before returning to the laboratory (Teagasc Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland; 52°09′N; 8°16′W), where it was stored at −20°C. Pre-grazing compressed sward height was determined by recording 30 measurements diagonally across each paddock using a rising plate meter (diameter 355 mm, 3.2 kg/m^2; Jenquip, Feilding, NZ). Sward density was calculated as described by Dineen et al. (2021a). These measurements were used to calculate sward density and pre-grazing herbage mass as described by Dineen et al. (2021a):

$$\text{Pre-grazing herbage mass (kg DM/ha)}$$
$$= [\text{Pre-grazing compressed sward height (cm)}$$
$$- 4 \text{ (cm)}] \times \text{sward density (kg of DM/cm per ha)}.$$

The 2 most recently grazed paddocks on each farm were used to determine post-grazing compressed sward height by recording 30 measurements diagonally across each paddock using a rising plate meter.

Sward Nutritive Value Analysis

All pasture samples were freeze-dried (LS40+ chamber, MechaTech System Ltd.) at −55°C for at least 72 h and, once dried, were milled through a 1-mm screen using a Cyclotech 1093 Sample Mill (Foss, Hillerød, Denmark). From a resource use-efficiency perspective, pasture samples from 7 of the 10 grazing rotations were initially selected for full nutritive value analysis (n = 168). The 7 grazing rotations selected were; 1 (March); 2 (April); 3 (May); 4 (early June); 5 (late-June); 7 (late July and early August); and 9 (late September and early October). In addition, 12 of the 25 farms were randomly selected for the full nutritive value analysis, ensuring a representative geographical distribution. Pasture samples were analyzed for CP using a Leco FP-928 (Leco Australia Pty Ltd., Baulkham Hills, Australia; AOAC, 1990, method 990.03), ash (AOAC, 2000, method 942.05), and organic matter digestibility (**OMD**; Morgan et al., 1989) using the Fibertec Systems analyzer (Foss, Ballymount, Dublin, Ireland), as well as NDF and ADF using an Ankom200 (Macedon, NY; Lee and Prosky, 1995, method 973.18). The NDF and ADF results are reported inclusive of residual ash. Pasture samples were also analyzed for concentration and digestibility of amylase- and sodium sulfite–treated NDF corrected for ash residue (**aNDFom**), in accordance with Raffrenato et al. (2018), with the inclusion of a 12-h time point as described by Dineen et al. (2021b). Samples were analyzed for mineral concentrations using inductively coupled plasma mass spectrometry, except for Cl, which was determined using a titration method (FBA Laboratories Ltd., Cappoquin, Ireland). The FA concentration and composition of pasture samples were determined via gas chromatography. Fatty acid methyl esters (**FAME**) were extracted and methylated in duplicate using the rapid microwave-assisted technique as outlined by Brunton et al. (2015). Analysis was performed using a Thermo Trace 1600 Series GC (Thermo Fisher Scientific, Waltham, MA) equipped with a flame ionization detector. Injections were handled by a Triplus RSH autosampler, with a programmable temperature vaporization inlet set to 250°C, with a 50:1 split ratio, and an injection volume of 1 μL. The flame ionization detector was held at 250°C. Separation of FAME was achieved on an RT-2560 fused silica column with a nonbonded biscyanopropyl polysiloxane phase (100 m × 0.25-mm i.d., 0.2-μm film thickness; Thames Restek UK Ltd.). The column temperature program began at 60°C, held for 5 min, increased to 165°C at a rate of 15°C/min, held for 1 min, and then increased to 225°C at 2°C/min with a final hold of 35 min, for a total run time of 78 min. Helium was the carrier gas and maintained at a constant pressure of 224,143 Pa. A 37-component FAME mix was used to calculate individual FAME response factors from the response of the C13 FAME peak. These response factors were used to quantify each FAME peak using the amount of internal standard added to the sample.

Bulk Tank Milk Samples

A bulk tank milk sample, with an even proportion of a.m. and p.m. milkings, was collected during each visit. The milk was agitated before sampling and collected using a disposable dipping bottle. Samples were placed on ice during transport and were then stored at 4°C, before milk composition analysis. Samples were analyzed using a Milkoscan 7 RM (Foss Electric, Hillerød, Denmark) for milk fat, CP, and lactose concentrations. Milk mid-infrared (**MIR**) data were used to predict milk FA composition in accordance with Soyeurt et al. (2011). This was performed by the Irish Cattle Breeders Federation (Co. Cork, Ireland), using prediction equations developed as part of the OptiMIR project (Grelet et al., 2014). Milk FA subgroups were calculated similar to Benoit et al. (2024) for de novo FA, mixed FA, and preformed FA. The n-3/n-6, spreadability, and desaturase index were calculated as described in Timlin et al. (2023).

Farm Management

All farms recorded animal information, fertilizer application, and grassland management on the PBI online decision support tool (https://pasturebase.teagasc.ie/V2/login.aspx ; Hanrahan et al., 2017). Following completion of farm sampling, data from each farm's PBI account for the 2-yr period was extracted. Data relating to average farm cover, growth rate, target pre-grazing herbage mass, number of cows milking, pasture allocation, concentrate supplementation level, silage supplementation level, and N, P, and K fertilizer application were incorporated into the experiment's data set. Data relating to the herds' genetic characteristics, which included Economic Breeding Index (**EBI**) and PTA for milk traits, were obtained for the 2-yr period.

Statistical Analysis, Model Development, and Model Evaluation

All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC). All data fitted the assumption of normality, and no transformations were required. As discussed previously, pasture samples from 12 of the 25 farms were initially selected for full nutritive value analysis. Thus, the data from this subset of farms were put forward as the model development data set. Data from the remaining 13 farms were used for the purpose of the independent model evaluation data set. Descriptive statistics for all data sets were generated using PROC MEANS. Simple associations between explanatory variables and milk fat concentration were visualized using simple linear regression (PROC REG).

To investigate the effects of grazing rotation on several variables, a linear mixed effects model was used (PROC MIXED), which included the fixed effect of grazing rotation and the random effects of farm and farm nested in year to account for the repeated measurements taken on farms across and within years. Means were determined using the LSMEANS statement, and multiple comparisons between grazing rotation means were made using the Tukey–Kramer method. Significance was considered at $P \leq 0.05$.

To quantify each explanatory variable's association with milk fat concentration, a univariate linear mixed effects model was used (PROC MIXED), which included the random effects of farm and farm nested in year. The corresponding partial regression coefficients, 95% CI, and P-values are reported. Statistical association was considered if $P < 0.2$. Multicollinearity among variables was assessed using the Spearman option in PROC CORR and the variance inflation factors (**VIF**) option in PROC REG. Variables with VIF > 10 or r > 0.8 were deemed collinear, and the most collinear variable was removed from model development.

Variables that had a univariate analysis of $P < 0.2$ were included in a multivariable linear regression model (PROC MIXED), which accounted for the random effect of farm and farm nested in year. Backward stepwise manual elimination was performed to select a parsimonious model that contained only individual variables that were statistically significant ($P < 0.05$). The corresponding partial regression coefficients, 95% CI, and P-values of the model are reported. The predictive performance of the multivariable linear regression model was initially assessed across 7 rotations, for both the model development and model evaluation data sets, using regression analysis (PROC REG). Evaluation criteria included the coefficient of determination (R^2), average bias, slope between observed and predicted milk fat concentrations, root mean square error (**RMSE**), and relative prediction error (**RPE**), as described by Fuentes-Pila et al. (1996) and Zom et al. (2012). Based on the variables selected during the backward stepwise elimination, the multivariable linear regression model was expanded to all 10 rotations and subsequently assessed using the model evaluation data set. The predictive performance of the 10-rotation multivariable linear regression model was assessed as described previously.

RESULTS

Descriptive statistics relating to the commercial farm data set are presented in Tables 1 and 2 and Supplemental Table S1 (see Notes). The average herd size was 234 cows, with 21% of the animals being primiparous. Herd average EBI was (mean ± SD) €172 ± 14.0, with a range of €148 to €202. Herd average milk fat concentration PTA was 0.19% ± 0.04%, with a range of 0.08% to 0.26%. The average herd milk fat concentration across the 2-yr period was 4.54% ± 0.50%, with a range of 3.56% to 6.09%. The herd average de novo, mixed, and preformed FA were 27.9 ± 2.0, 32.5 ± 1.6, and 37.5 ± 3.3 g/100 g fat, respectively. The patterns of milk fat concentration and milk FA subgroups across the year are presented in Figure 1. An average pre-grazing herbage mass of 1,695 ± 418 kg of DM/ha was observed, with a range of 606 to 2,586 kg of DM/ha observed. The average aNDFom concentration, FA concentration, and OMD were 35.1% ± 3.8% of DM, 2.33% ± 0.74% of DM, and 82.3% ± 2.7% of OM, respectively (Table 2). Simple linear regressions between (a) pre-grazing mass, (b) aNDFom, (c) FA concentration, and (d) OMD and bulk tank milk fat concentration are presented in Figure 2.

The effects of grazing rotation on several variables are presented in Table 2, Supplemental Table S2 (see Notes), and Figure 1. Grazing rotation had an effect on milk fat concentration, with a reduction observed from grazing rotation 1 to a nadir in grazing rotation 3, remaining low

Table 1. Descriptive statistics of herd characteristics and milk composition on 25 Irish dairy herds over a 2-yr period

Item[1]	n	Mean	SD	Minimum	Maximum
Number of cows	25	234	101	106	541
Primiparous	25	55	39	11	224
Multiparous	25	191	90	84	494
Previous 305-d milk fat, %	25	4.55	0.21	4.08	4.86
Previous 305-d milk yield, kg	25	6,027	592	4,512	6,824
Previous 305-d milk solids yield, kg	25	502	44	383	561
Concentrate fed, kg of fresh weight/cow per year	25	865	211	599	1,555
Breed composition, HF:JE	25	68:32	—	50:50	100:0
EBI, €	25	172	14	148	202
Milk subindex, €	25	57	8	38	74
PTA					
Milk, kg	25	−24.2	43.9	−104	93
Fat, %	25	0.19	0.04	0.08	0.26
Protein, %	25	0.11	0.02	0.07	0.15
Fat, kg	25	10.0	1.6	5.5	13.4
Protein, kg	25	5.8	1.1	3.6	8.4
Milk composition					
Fat, %	441	4.54	0.50	3.56	6.09
De novo, g/100g of fat	356	27.9	2.0	23.0	32.4
Mixed, g/100g of fat	354	32.5	1.6	28.7	36.6
Preformed, g/100g of fat	355	37.5	3.3	30.0	44.8
Protein, %	445	3.79	0.29	3.00	4.65
Lactose, %	439	4.75	0.15	4.35	5.10

[1]HF = Holstein-Friesian; JE = Jersey; EBI = Economic Breeding Index; de novo = fatty acids C4–C14; mixed = fatty acids C16, C16:1; preformed = fatty acids greater than or equal to C17.

before increasing from grazing rotations 5 to 10. Grazing rotation had an effect on milk FA subgroups, with a reduction in preformed FA from grazing rotations 1 to 3, whereas de novo FA increased from grazing rotations 1 to 4. Grazing rotation also had an effect on all other predicted milk FA parameters (Supplemental Table S2). Pre-grazing herbage mass reduced from grazing rotation 1 to a nadir in rotation 5, before increasing for the remainder of grazing rotations. Grazing rotation had an effect on all pasture nutritive value parameters (Table 2).

Univariate analysis identified 27 relationships ($P < 0.2$) between explanatory variables and milk fat concentration following multicollinearity analysis (Table 3). Variables removed due to multicollinearity included pre-grazing compressed sward height, post-grazing compressed sward height, milk fat yield PTA (kg), milk protein concentration PTA, NDF, several pasture FA (C14:0, C16:0, C18:0, C18:1, C18:2, and C18:3), herd average concentrate intake, and pasture regrowth period.

After the backward stepwise elimination of variables, grazing rotation ($P < 0.01$) and the herd's milk fat concentration PTA ($P < 0.01$) were identified as factors associated with bulk tank milk fat concentration in the multivariable linear regression. The partial regression coefficients, 95% CI, and P-values of the 7-rotation model are presented in Table 4. For the model development data set, the 7-rotation multivariable linear regression model predicted bulk tank milk fat concentration with R^2 of 0.63 and RMSE of 0.25%. The slope between observed and predicted milk fat concentration was 1.00 (SE = 0.06), with average bias of −0.001% and RPE of −0.02. The residuals from the model were normally distributed.

Results from the independent model evaluation, performed using data from the additional 13 farms across 7 rotations, are presented in Figure 3. The model predicted bulk tank milk fat concentration with R^2 of 0.73 and RMSE of 0.23%. The slope between observed and predicted milk fat concentration was 1.15 (SE = 0.06), with average bias of 0.05% and RPE of 1.09. The residuals from the model were normally distributed. The multivariable linear regression model predicted a mean milk fat concentration of 4.45% ± 0.32% with a range of 3.95% to 5.29%.

Based on the strong predictive performance of the 7-rotation model and the variables identified by the backward stepwise elimination (i.e., grazing rotation and the herd's milk fat concentration PTA), a final model development step was conducted, whereby the multivariable linear regression model was expanded to all 10 rotations. The corresponding partial regression coefficients, 95% CI, and P-values of the model are presented in Table 5. Results from the independent evaluation of this final 10-rotation model are presented in Figure 4. The model predicted bulk tank milk fat concentration with R^2 of 0.79 and RMSE of 0.23%. The slope of the relationship between observed and predicted milk fat concentration was 1.09 (SE = 0.04), with average bias of 0.05% and RPE of 1.06. The multivariable linear regression model

Table 2. Descriptive statistics (arithmetic) of the effect of grazing rotation (LSM) on grazing parameters and pasture nutritive value on 12 Irish dairy herds over a 2-yr period

	Descriptive statistics[1]					Grazing rotation[2]								
Item[3]	n	Mean	SD	Minimum	Maximum	1	2	3	4	5	7	9	SEM	P-value
Grazing parameter														
Pre-grazing mass, kg DM/ha	164	1,695	418	606	2,586	1,881[a]	1,738[ab]	1,654[ab]	1,532[b]	1,442[b]	1,658[ab]	1,958[a]	83.88	<0.01
Pre-height, cm	166	9.9	1.9	5.9	15.3	10.3[ab]	9.1[b]	9.9[b]	10.0[ab]	9.4[b]	9.3[b]	11.4[a]	0.41	<0.01
Post-height, cm	160	4.3	0.5	2.7	5.6	4.0[b]	4.4[a]	4.4[a]	4.4[a]	4.3[ab]	4.3[ab]	4.4[a]	0.11	<0.01
Pasture nutritive value														
DM, %	168	17.6	3.1	10.4	26.5	18.4[ab]	17.6[ab]	16.9[b]	18.4[ab]	19.4[a]	19[a]	13.6[c]	0.58	<0.01
CP, % DM	167	18.1	3.8	10.5	30.1	21.6[a]	19.2[b]	18.2[bc]	15.6[d]	16.1[cd]	15.8[d]	20.6[ab]	0.67	<0.01
OMD, % OM	166	82.3	2.7	74.8	87.6	82.5[b]	84.7[a]	84.7[a]	82.9[b]	81.6[bc]	78.8[d]	80.4[c]	0.40	<0.01
aNDFom, % DM	168	35.1	3.8	26.7	46.5	35.4[b]	32.1[d]	32.6[cd]	34.3[bcd]	34.6[bc]	38.0[a]	38.5[a]	0.69	<0.01
$pdNDFom_1$, % aNDFom	168	48.8	17.5	20	80	51.4[bc]	66.0[a]	36.5[d]	46.8[bcd]	55.1[ba]	45.8[bcd]	40.1[cd]	3.11	<0.01
$pdNDFom_2$, % aNDFom	168	38.2	16.7	1.0	71.0	37.3[bc]	23.9[d]	51.9[a]	39.8[abc]	31.1[cd]	36.7[bc]	46.7[ab]	2.96	<0.01
$uNDFom_{240h}$, % aNDFom	168	12.5	3.3	5.4	22.7	10.8[de]	9.6[e]	11.2[cde]	12.9[bc]	13.3[b]	17.1[a]	12.7[bcd]	0.50	<0.01
$uNDFom_{240h}$, % DM	168	4.4	1.4	1.8	9.6	3.8[cde]	3.1[e]	3.7[de]	4.4[bcd]	4.6[bc]	6.5[a]	4.9[b]	0.22	<0.01
k_1	168	23.1	11.6	5.2	40.0	22.4[ab]	15.9[b]	27.9[a]	26.7[a]	19.8[ba]	24.5[ab]	24.6[ab]	2.28	<0.01
k_2	168	2.9	0.7	0.8	3.5	3.0[a]	2.6[a]	3.1[a]	2.6[a]	2.9[a]	3.0[a]	3.0[a]	0.14	<0.05
kd	168	5.9	1.5	3.4	10.6	6.4[ab]	7.0[a]	5.0[c]	5.7[bc]	6.0[abc]	6.0[abc]	5.3[bc]	0.28	<0.01
NDF, % DM	167	39.7	4.7	29.7	53.2	39.1[bc]	35.6[d]	36.4[cd]	38.6[bc]	40.1[b]	44.2[a]	44.2[a]	0.80	<0.01
ADF, % DM	166	21.1	2.3	16.4	26.4	19.8[cd]	19.2[d]	19.7[cd]	21.0[bc]	21.2[b]	22.9[a]	24.1[a]	0.36	<0.01
FA, % DM	151	2.33	0.74	0.91	4.59	2.76[a]	2.14[bc]	2.17[b]	1.70[c]	2.00[bc]	2.26[b]	3.12[a]	0.13	<0.01
FA (g/100g FA)														
C14:0	150	0.55	0.18	0.27	1.12	0.49[b]	0.63[a]	0.53[ab]	0.64[a]	0.57[ab]	0.61[a]	0.45[b]	0.04	<0.01
C16:0	151	20.06	4.87	13.22	35.05	16.87[d]	20.75[abc]	19.92[bcd]	23.75[a]	22.84[ab]	19.93[bcd]	18.07[cd]	0.98	<0.01
C18:0	147	2.43	0.72	1.48	5.29	2.01[c]	2.49[bc]	2.42[bc]	3.02[a]	2.68[ab]	2.41[bc]	2.13[bc]	0.15	<0.01
C18:1	150	4.46	2.08	1.7	12.21	2.95[d]	4.61[bc]	4.52[bc]	6.07[a]	5.84[ab]	4.25[cd]	3.7[cd]	0.42	<0.01
C18:2	148	10.75	1.29	6.99	13.54	11.77[a]	10.15[b]	10.02[b]	10.04[b]	9.94[b]	11.35[a]	11.56[a]	0.25	<0.01
C18:3	152	49.46	9.92	21.39	64.27	57.36[a]	48.04[bcd]	50.37[bc]	42.67[d]	44.57[cd]	47.95[bcd]	52.52[ab]	1.96	<0.01
Total SFA	151	33.48	9.65	14.97	62.28	27.05[d]	34.09[abc]	33.2[bc]	39.69[a]	38.95[ab]	34.36[abc]	30.51[cd]	1.97	<0.01
Total MUFA	151	6.06	2.68	1.68	15.12	4.12[d]	6.39[abc]	6.19[abc]	7.8[a]	7.68[ab]	6.06[bc]	5.07[cd]	0.54	<0.01
Total PUFA	151	64.41	9.95	34.28	78.32	71.93[a]	63.49[bcd]	64.98[bc]	57.31[d]	58.56[cd]	63.81[bc]	67.53[ab]	2.00	<0.01
Ash, % DM	166	9.71	1.37	5.57	13.69	9.15[b]	9.56[b]	9.71[ab]	9.25[b]	9.56[b]	10.0[ab]	10.7[a]	0.27	<0.01

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

[1]Arithmetic statistics of data relating to the model development population.

[2]Effect of grazing rotation on grazing parameters and pasture nutritive value (LSM).

[3]OMD = OM digestibility; aNDFom = amylase- and sodium sulfite–treated NDF corrected for ash residue; $pdNDFom_1$ = potentially digestible aNDFom fast fraction, % of aNDFom; $pdNDFom_2$ = potentially digestible aNDFom slow fraction, % of aNDFom; $uNDFom_{240h}$ = undigested aNDFom after 240 h of in vitro fermentation, % of aNDFom or % of DM; k_1 = digestion rate of the fast fraction, h^{-1}; k_2 = digestion rate of the slow fraction, h^{-1}; kd = digestion rate of pdNDFom, h^{-1}; NDF and ADF expressed inclusive of ash; FA = fatty acid; pre-height = compressed sward height of pasture prior to grazing; post-height = compressed sward height of pasture post-grazing.

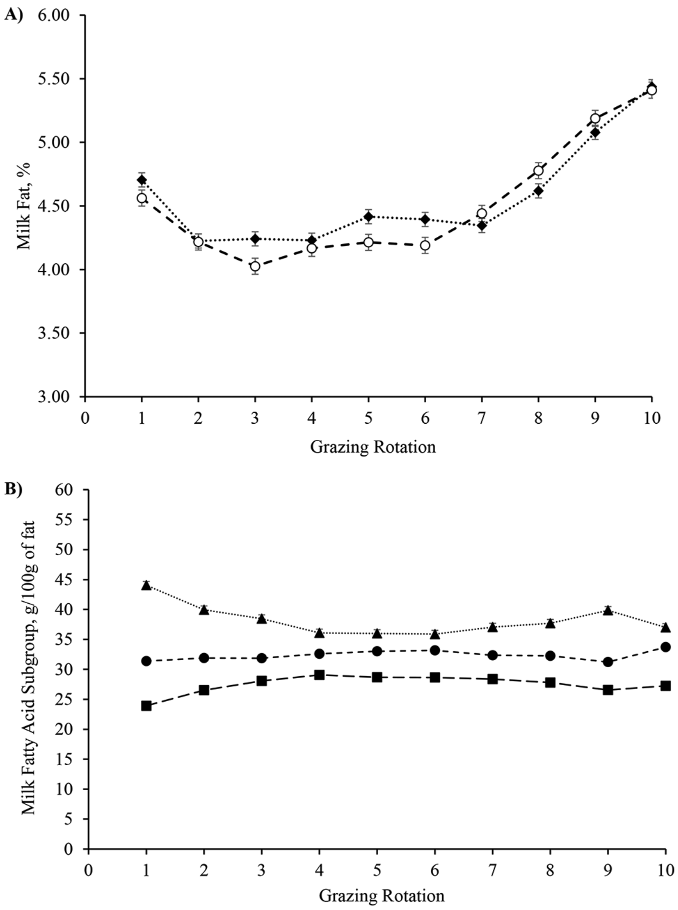

Figure 1. Bulk tank (LSM ± SEM; A) milk fat (%) for 2021 (♦) and 2022 (○) and (B) milk fatty acid subgroup (g/100 g of fatty acid) for 25 Irish dairy herds across 10 grazing rotations over a 2-yr period. De novo (■) = fatty acids C4–C14; mixed (●) = fatty acids C16 and C16:1; preformed (▲) = fatty acids greater than or equal to C17.

estimated a mean milk fat concentration of 4.56% ± 0.41%, with values ranging from 3.91% to 5.63%.

DISCUSSION

Reduced milk fat concentration or MFD is a major financial and psychological concern for dairy producers in pasture-based systems, especially during late spring and early summer. Many mechanisms have been implicated in this reduction, and a wide range of intervention strategies have been suggested; however, successful consistent responses from such strategies are rare. In the current observational experiment, univariate analysis identified several specific nutritional and non-nutritional factors that were associated with the bulk tank milk fat concentration of commercial spring-calving grazing dairy herds, which supports our hypothesis. However, these specific associations were not retained in our multivariable linear regression model, except for milk fat concentration PTA. Although an association between grazing rotation and bulk tank milk fat concentration was retained, this relationship is likely multifactorial. It is critical to disentangle the nutritional and non-nutritional factors that could be contributing to this association between grazing rotation and bulk tank milk fat concentration. This could allow the development of effective intervention strategies or could provide an understanding that some of the contributing factors, such as stage of lactation and photoperiod length, are outside the control of management.

Association Between Grazing Rotation and Milk Fat Concentration

In the current experiment, the effect of grazing rotation on milk fat concentration was consistent across both sampling years (Figure 1). This curvilinear relationship observed across grazing rotations has previously been reported in pasture-based dairy production systems (O'Callaghan et al., 2016) and aligns with monthly bulk tank milk fat concentration observed in Ireland (CSO, 2024). This curvilinear pattern likely occurs due to a multitude of factors, including stage of lactation, pasture nutritive value, and environmental conditions (Timlin et al., 2021).

Stage of Lactation Associations. The animal's stage of lactation, independent of the effects of nutrition and season, has been suggested to affect milk yield and milk composition due to changes in physiological state (Walker et al., 2004). In the current experiment, all herds were compact spring-calving systems with moderate variability in the average DIM within or between herds. Stage of lactation leads to a peak in milk production at 49 to 56 DIM and begins to decline after 70 DIM (O'Sullivan et al., 2019). In contrast, milk fat concentration typically reaches a nadir at 40 to 60 DIM before increasing for the remainder of lactation. This reduction in milk fat concentration has been partially linked to a dilution effect due to increased milk yield and lactose synthesis (Holmes et al., 1987). Silvestre et al. (2009) concluded that the most likely behavior of the milk fat concentration lactation curve is the inverse of the milk yield lactation curve. The highest prevalence of MFD for spring-calving cows has also been reported during this period (Carty et al., 2017). As peak milk production and peak energy demand occur before animals reach maximum DM intake capability, a period of negative energy balance might be experienced (Butler, 2000). Negative energy balance can lead to alterations in milk FA compositions, with increased preformed FA synthesis occurring due to increased incorporation of long-chain FA derived from adipose tissue mobilization and a coinciding reduction in de novo FA synthesis (Palmquist et al., 1993). In the current experiment, the greatest concentrations

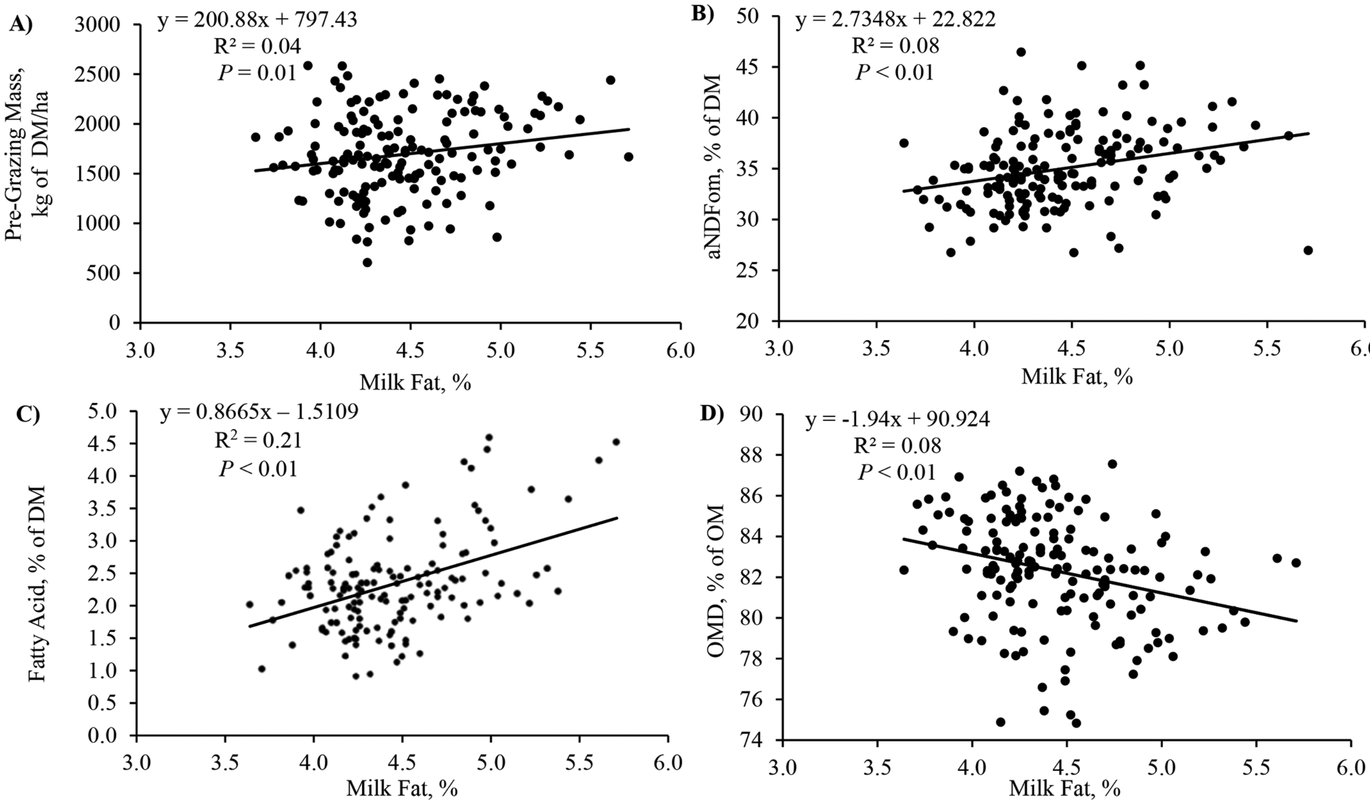

Figure 2. Relationship between (A) pre-grazing mass (kg of DM/ha), (B) aNDFom concentration (% of DM), (C) fatty acid concentration (% of DM), and (D) OM digestibility (OMD; % of OM) and bulk milk fat (%) for 12 Irish herds across 7 grazing rotations over a 2-yr period. aNDFom = amylase- and sodium sulfite–treated NDF corrected for ash residue.

of performed FA and lowest concentrations of de novo FA were observed during grazing rotation 1 (Figure 1). This was followed by a reduction in preformed FA and an increase in de novo FA concentrations for subsequent grazing rotations. It is important to highlight that milk FA in the current experiment were predicted by MIR methods, which are unlikely to be as accurate and precise as chemical methods. Although stage of lactation could be involved in MFD, Carty et al. (2017) demonstrated that the greatest prevalence for a reduction in milk fat concentration for both spring- and autumn-calving cows occurred in the month of May, therefore irrespective of stage of lactation or DIM. It is likely that time of year, or other factors related to time of year, could be having a greater influence on milk fat concentration than stage of lactation (Auldist et al., 1998).

Pasture Nutritive Value Associations. In pasture-based systems, grassland management practices are employed to maintain the pastures at an optimal maturity for grazing (i.e., 1,500 kg of DM/ha; Doyle et al., 2023). In the current experiment, a similar average pre-grazing herbage mass was observed (1,695 kg of DM/ha) when compared with the optimal, with a range of 606 to 2,586 kg of DM/ha. A curvilinear pattern emerged in pre-grazing herbage mass, which was similar to the pattern observed for bulk tank milk fat concentration (Table 2). The pattern in pre-grazing herbage mass likely occurred due to pasture management techniques, which are designed to increase average farm cover during the shoulders of the year, when pasture growth rates are lower than mid-season growth rates (O'Donovan and Delaby, 2016). The relationship between milk fat concentration and pre-grazing herbage mass likely depends on pasture nutritive value, which can change due to time of year (McEvoy et al., 2009). Insufficient aNDFom concentration in immature pasture has been suggested to cause reduced milk fat concentration (Kelly et al., 1998). The digestion of aNDFom provides an important source of acetate and butyrate for milk fat synthesis (Chilliard et al., 2000). In the current experiment, univariate analysis suggested a positive relationship between aNDFom and bulk tank milk fat concentration, with every 1% increase in aNDFom leading to a 0.03% increase in milk fat concentration. This positive relationship would suggest that low concentrations of aNDFom could lead to reduced milk fat concentration, with previous research supporting this

Table 3. Univariate linear regression analysis of variables associated with bulk tank milk fat (%) on 12 Irish dairy herds across 7 grazing rotations over a 2-yr period

Variable[1]	Partial regression coefficient	95% CI	P-value
Grazing rotation			
9	Referent		
7	−0.6427	−0.78, −0.51	<0.01
5	−0.7735	−0.91, −0.64	<0.01
4	−0.8994	−1.04, −0.76	<0.01
3	−0.9035	−1.04, −0.77	<0.01
2	−0.8235	−0.96, −0.69	<0.01
1	−0.4446	−0.58, −0.3	<0.01
Pre-grazing mass, kg of DM/ha	0.0002	0.00005, 0.00034	<0.01
DM, %	−0.0525	−0.07, −0.03	<0.01
CP, % of DM	0.0036	0.002, 0.005	<0.01
Ash, % of DM	0.0052	0.001, 0.01	0.02
ADF, % of DM	0.0063	0.004, 0.009	<0.01
OMD, % of OM	−0.0040	−0.006, −0.002	<0.01
aNDFom, % of DM	0.0333	0.02, 0.05	<0.01
uNDFom$_{240h}$, % DM	0.0302	−0.01, 0.07	0.17
Mg, %	3.2568	1.57, 4.95	<0.01
P, %	2.6331	1.64, 3.62	<0.01
S, %	2.4630	1.5, 3.43	<0.01
K, %	0.1872	0.09, 0.29	<0.01
Cl, %	0.2458	0.07, 0.42	<0.01
Mn, mg/kg	−0.0025	−0.006, 0.001	0.12
Fe, mg/kg	−0.0006	−0.0011, −0.0002	<0.01
Co, mg/kg	−0.9763	−1.97, 0.02	0.06
Cu, mg/kg	0.0730	0.04, 0.11	<0.01
Zn, mg/kg	0.0144	−0.001, 0.03	0.07
FA, % of DM	0.0241	0.02, 0.03	<0.01
SFA, g/100 g FA	−0.0078	−0.014, −0.001	0.02
MUFA, g/100 g FA	−0.0293	−0.05, −0.01	<0.01
PUFA, g/100 g FA	0.0076	0.001, 0.014	0.02
Growth rate, kg DM/ha per day	−0.0025	−0.00496, −0.00001	0.05
EBI	0.0046	−0.001, 0.01	0.12
Milk yield PTA, kg	−0.0019	−0.00402, 0.0002	0.07
Milk fat PTA, %	2.6460	0.92, 4.37	<0.01

[1]OMD = OM digestibility; aNDFom = amylase- and sodium sulfite–treated NDF, corrected for ash residue; uNDFom$_{240h}$ = undigested aNDFom after 240 h of in vitro fermentation, % of DM; FA = fatty acid; EBI = Economic Breeding Index.

when NDF concentration was less than 25% (Stockdale et al., 1987). However, in the current experiment, the average NDF concentrations observed across all grazing rotations were greater than the minimal NDF requirements suggested by both Stockdale et al. (1987; >25% of DM) and Kolver, (2000; >35% of DM) for pasture-fed cows. In addition, although simple linear regression analysis of aNDFom and milk fat concentration was significant ($P < 0.01$; Figure 2), it explained only a small proportion of the variation ($R^2 = 0.08$). Rivero and Anrique (2015) suggested possible associations between reduced milk fat concentration and the aNDFom concentrations and aNDFom digestibility of pasture at specific times of year. Notably, in the current experiment, grazing rotation 2 exhibited the lowest concentration of aNDFom with the highest rate of aNDFom digestibility. However, a large commercial farm experiment by Neville et al. (2023) observed no effect of pasture NDF concentration on milk fat concentration, suggesting that low pasture aNDFom concentrations alone might not be sufficient to induce reduced milk fat concentration.

High pasture FA concentrations, particularly UFA, have also been suggested to reduce milk fat concentration (Rivero and Anrique, 2015). Unsaturated FA, such as C18:2 and C18:3, are biohydrogenated within the rumen and, if unfavorable rumen conditions are present, milk fat-inhibiting bioactive isomers can be produced (Bauman and Griinari, 2001). Increasing the amount of UFA entering the rumen can negatively affect the rumen environment by reducing bacteria's ability to fully biohydrogenate UFA (Rivero and Anrique, 2015). Harvatine and Allen (2006) reported that increased UFA concentrations slowed the biohydrogenation of C18:1, which in turn reduced milk fat concentration. Although the typical concentrations of FA in pasture are relatively low, large daily intakes of pasture among grazing dairy cows can lead to considerable amounts of FA being ingested (Elgersma et al., 2003), the majority of which are

Table 4. Parsimonious multivariable linear regression model[1] of factors associated with bulk tank fat (%) on 12 Irish dairy herds across 7 grazing rotations over a 2-yr period

Variable	Partial regression coefficient	95% CI	*P*-value
Intercept	4.6217	4.30, 4.94	<0.01
Grazing rotation			
9	0	Referent	—
7	−0.6441	−0.78, −0.51	<0.01
5	−0.7749	−0.91, −0.64	<0.01
4	−0.9008	−1.03, −0.77	<0.01
3	−0.9042	−1.04, −0.77	<0.01
2	−0.8196	−0.96, −0.68	<0.01
1	−0.4425	−0.58, −0.31	<0.01
Milk fat PTA, %	2.5561	0.92, 4.20	<0.01

[1]Explanatory variables identified in univariate analysis ($P < 0.2$) were included in the model, and backward stepwise elimination was used until all variables had $P < 0.05$ and the most parsimonious model was achieved.

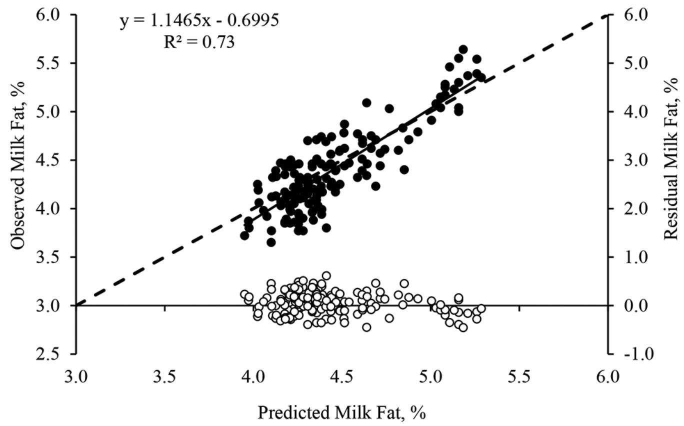

Figure 3. Observed bulk tank milk fat (%) versus bulk tank milk fat (%) predicted by the parsimonious multivariable linear regression model (●). The solid line (—) represents the linear regression, and the dashed line (- - -) is the unity line. Conditional residuals are also presented (○). Evaluation was performed using data from 13 additional farms across 7 grazing rotations over a 2-yr period.

PUFA (Clapham et al., 2005). In the current experiment, grazing rotations with the greatest pasture FA and PUFA concentrations coincided with the greatest herd bulk tank milk fat concentrations, resulting in positive univariate associations between pasture FA and PUFA concentration and bulk tank milk fat concentrations (Table 3). This suggests that pasture FA and PUFA concentrations may not be negatively associated with milk fat concentration, within the ranges observed in the current experiment. In contrast, a negative univariate association between bulk tank milk fat concentration and pasture MUFA was observed (Table 3). A similar negative effect of pasture MUFA on milk fat was reported by Neville et al. (2023), who observed that herds with low milk fat concentration consumed pasture with greater concentrations of MUFA. Although the explanation for a negative association between pasture MUFA concentrations and milk fat concentration is unclear, in the current experiment pasture C18:1 concentrations were the primary contributor to MUFA concentrations. Dewanckele et al. (2020) reported the possible isomerization of *cis*-9 C18:1 to *trans*-10 C18:1, which has been frequently linked to dairy cow diets associated with reduced milk fat synthesis (Shingfield and Griinari, 2007). He et al. (2012) reported increased rumen outflow of *trans*-10 C18:1 during reduced milk fat synthesis in TMR diets; however, the relationship between *trans*-10 C18:1 and reduced milk fat concentration in pasture-based production systems is not well understood. Rugoho et al. (2017) reported increased *trans*-10 C18:1 concentrations during diet-induced MFD at pasture, although the effect was dependent on concentrate supplementation. Although the association between pasture MUFA and milk fat concentration is unclear, Bauman et al. (2008) suggested that the future discovery of milk fat-inhibiting bioactive isomers might implicate other alternative biohydrogenation pathways. Furthermore, Rulquin et al. (2007), who attributed 34% of the observed reductions in milk fat synthesis to *trans*-10 FA (i.e., *trans*-10 C18:1 and *trans*-10, *cis*-12 CLA), concluded that the reductions in milk fat concentration could be multifactorial, and the authors proposed that a multinutrient approach should be adopted to better understand the variability of milk fat concentration.

Environmental Conditions Associations. Circadian rhythms could be involved in the curvilinear relationship between milk fat concentration and grazing rotation. Annual patterns in milk production have been reported in nonseasonal dairy systems in the northern hemisphere, with the highest milk fat concentration observed during winter and the lowest during summer (Salfer et al., 2019). Although these annual rhythms have been associated with a 0.30% fluctuation in milk fat concentration (Salfer and Harvatine, 2018), the mechanisms remain unclear. Historically, these patterns have been linked to environmental factors such as changes in forage quality and heat stress; however, more recent research has implicated the possible effect of endogenous annual rhythms within dairy cows, which can control milk synthesis (Salfer and Harvatine, 2018). The magnitude of milk fat concentration fluctuation due to annual rhythms appears to depend on latitudinal location. Salfer et al. (2019) reported a milk fat concentration amplitude (i.e., peak to mean) ranging from 0.07% to 0.14%, with a larger amplitude observed the farther the farm was located from the equator. New Zealand, due to its location in the southern hemisphere, observes a reciprocal seasonality compared with Ireland and observes an annual peak in milk fat concentration from June to August (Auldist et al., 1998), which may indicate an effect of latitude on milk fat

Table 5. Parsimonious multivariable linear regression model[1] of factors associated with bulk tank fat (%) on 12 Irish dairy herds across 10 grazing rotations over a 2-yr period

Variable	Partial regression coefficient	95% CI	*P*-value
Intercept	4.8766	4.52, 5.23	<0.01
Grazing rotation			
10	0	Referent	—
9	−0.3195	−0.46, −0.18	<0.01
8	−0.6751	−0.82, −0.53	<0.01
7	−0.9639	−1.10, −0.82	<0.01
6	−1.0980	−1.24, −0.95	<0.01
5	−1.0947	−1.24, −0.95	<0.01
4	−1.2206	−1.36, −1.08	<0.01
3	−1.2230	−1.37, −1.08	<0.01
2	−1.1434	−1.29, −1.00	<0.01
1	−0.7669	−0.91, −0.62	<0.01
Milk fat PTA, %	2.9031	1.10, 4.71	<0.01

[1]Explanatory variables identified in univariate analysis ($P < 0.2$) were included in the model and backward stepwise elimination was used until all variables had $P < 0.05$ and the most parsimonious model was achieved.

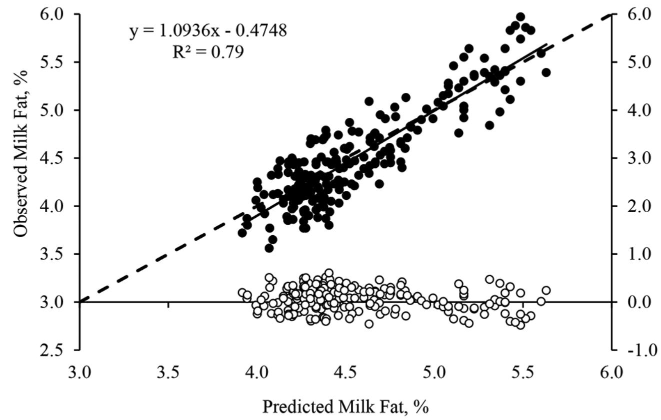

Figure 4. Observed bulk tank milk fat (%) versus bulk tank milk fat (%) predicted by the parsimonious multivariable linear regression model (●). The solid line (—) represents the linear regression, and the dashed line (- - -) is the unity line. Conditional residuals are also presented (○). Evaluation was performed using data from 13 additional farms across 10 grazing rotations over a 2-yr period.

concentration (Salfer et al., 2019). The effect of annual rhythms has been demonstrated to occur regardless of an animal's genetics or parity (Salfer et al., 2019), with day length and, by extension, photoperiod attributed to these annual changes. In a randomized controlled experiment, photoperiod has been observed to affect milk production with increased milk yield observed under 16 h of light per day; however, no effect on milk fat concentration was observed (Dahl et al., 2000). In the current experiment, the observed milk fat concentration amplitude of 0.87% is considerably larger than amplitudes previously reported due to annual rhythms. This indicates that the effect of annual rhythms alone might not account for the majority of variation in milk fat concentration across grazing rotations. That said, further investigation is clearly warranted to better understand the contribution of annual rhythms to changes in milk fat concentration.

Association Between Milk Fat Concentration PTA and Milk Fat Concentration

In the current experiment, we observed a wide range in herd milk fat concentration PTA, ranging from 0.08% to 0.26% (Table 1). The observed range in bulk tank milk fat concentration was 3.56% to 6.09% (Table 1). We found a positive univariate association between milk fat concentration PTA and bulk tank milk fat concentration (Table 3). In addition, milk fat concentration PTA was retained in the multivariable linear regression model with a positive partial regression coefficient. The partial regression coefficient suggested that, for every 0.1% increase in milk fat concentration PTA, an associated increase of 0.25% to 0.29% in predicted milk fat concentration occurred (Tables 4 and 5). O'Sullivan et al. (2019) identified a strong correlation between milk fat concentration PTA and observed milk fat concentration in genetically divergent Holstein-Friesian cows, with a 0.1% increase in milk fat concentration PTA resulting in a 0.28% increase in in milk fat concentration. Theoretically, a 1-unit increase in PTA should correspond to a 2-unit increase in the observed trait (Simm, 1998); however, Lahart et al. (2024) observed that a 0.1% increase in milk fat concentration PTA resulted in a 0.36% increase in milk fat concentration when compared within breed for genetically divergent Holstein-Friesian cows, and a 0.34% increase in milk fat concentration when compared between breeds of Holstein-Friesians and Jersey cows. Similarly, Heffernan et al. (2025b) observed that a 0.1% increase in milk fat concentration PTA corresponded to a 0.34% increase in milk fat concentration in Holstein-Friesian and Jersey cows during early to mid-lactation, highlighting the consistent influence of milk fat concentration PTA on observed milk fat concentration, regardless of breed or stage of lactation. It is important to acknowledge the underestimation of PTA on observed milk fat concentration. This discrepancy could be due to management factors, such as superior grassland management practices on research herds compared with standard practice on commercial farms upon which the base cows' production is evaluated (ICBF, 2023). Altogether, selecting animals for greater milk fat concentration PTA is a robust strategy to increase annual bulk tank milk fat concentration. However, it seems that a pattern of reduction in milk fat concentration during late spring to early summer still occurs for high milk fat concentration PTA herds, albeit from a greater baseline. Thus, there could be opportunity to accelerate genetic gain and phenotypic milk fat concentration performance by investigating whether the dynamic pattern in milk fat concentration across the year has specific genetic associations (Calus et al., 2005).

Application of the Milk Fat Concentration Model on Commercial Farms

The multivariable linear regression model developed in the current experiment has the capability to predict the bulk tank milk fat concentration of a herd throughout the grazing season, which was one of the primary objectives of this experiment. When the model was applied to an independent evaluation data set of 13 additional herds for the 7 grazing rotations, the model predicted bulk tank milk fat concentration with R^2 of 0.73 and RMSE of 0.23%. Furthermore, when the model was expanded and applied to 10 grazing rotations, the model predicted bulk tank milk fat concentration with R^2 of 0.79 and RMSE of 0.23%, indicating strong performance. Thus, this model can provide accurate and precise predictions of milk fat concentration for individual herds relative to specific time points in the year and the herd's genetic merit. The model includes parameters that are easily attainable on the majority of spring-calving dairy farms, and the expansion of the model to 10 grazing rotations improved applicability across the entire grazing period. Considerable negative deviation from the model predictions could suggest underlying issues on commercial farms, warranting management intervention and potential financial investment. This could allow for informed decision-making on-farm, identifying when to implement nutritional intervention strategies. Equally, alignment of predicted and observed milk fat concentrations could suggest that no intervention is required, as the herd is exhibiting typical seasonal effects, which could be associated with photoperiod or climate, or both (Walker et al., 2004). A notable observation from the current experiment was the consistent pattern in bulk tank milk fat concentration across both experimental years, which is also reflected in national Irish bulk tank milk data over the past 10 to 20 yr (CSO, 2024). This suggests that the factors contributing to a reduction in milk fat concentration are likely to follow a consistent seasonal pattern, rather than being driven by erratic variables such as weather conditions or substantial fluctuations in pasture chemical composition.

CONCLUSIONS

A consistent reduction in milk fat concentration during late spring and early summer represents a considerable financial loss for both milk producers and processors. This experiment investigated the relationship between nutritional and non-nutritional factors and bulk tank milk fat concentration on commercial grazing dairy farms. Several univariate relationships were identified; however, backward stepwise elimination identified a multivariable linear regression model with grazing rotation and the herd's milk fat concentration PTA as factors associated with bulk tank milk fat concentration. Although the association between grazing rotation and bulk tank milk fat concentration is likely multifactorial, the positive relationship between milk fat concentration PTA and milk fat concentration highlights the important role of genetics on milk fat production in pasture-based systems. The multivariable linear regression model can be easily implemented on-farm to identify deviations away from anticipated milk fat concentration, relative to specific time points in the year and herd genetic merit.

NOTES

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Nonstandard abbreviations used: aNDFom = amylase- and sodium sulfite–treated NDF, corrected for ash residue; EBI = Economic Breeding Index; FA = fatty acid; FAME = fatty acid methyl esters; HF = Holstein-Friesian; JE = Jersey; k_1 = digestion rate of the fast fraction; k_2 = digestion rate of the slow fraction; kd = digestion rate of pdNDFom; MIR = mid-infrared; MFD = milk fat depression; OMD = organic matter digestibility; PBI = PastureBase Ireland; $pdNDFom_1$ = potentially digestible aNDFom fast fraction; $pdNDFom_2$ = potentially digestible aNDFom slow fraction; RMSE = root mean square error; RPE = relative prediction error; $uNDFom_{240h}$ = undigested aNDFom after 240 h of in vitro fermentation; VIF = variance inflation factor.

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