Dry matter intake, milk performance and production efficiency from spring calving dairy cows offered grass-only, grass-white clover and total mixed ration diets.

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Abstract
In pasture-based dairy production systems, dry matter intake (DMI) is one of the main factors curtailing milk production and production efficiency. The inclusion of white clover (*Trifolium repens* L.) in swards of perennial ryegrass (PRG; *Lolium perenne* L.) can increase DMI from increased sward nutritive value over a grass-only sward. Feeding a fully balanced TMR diet can enhance milk production as a result of greater DMI and through greater control of feed quality. Therefore, the objective of this study was to determine the relationship between DMI, milk production, and energy efficiencies for dairy cows consuming different diets. A farm systems experiment was conducted from 2015-2021. The three treatments were: TMR (100% confinement; grass silage, maize silage, concentrate), grass-only herbage (GR), or grass-white clover herbage (CL). Dry matter intake was estimated 17 times over the duration of the study, using the n-alkane technique for the GR and CL treatments, and an electronic roughage intake control system for the TMR treatment. Simultaneously, milk production, and production efficiencies were also measured. Significant increases (P<0.001) in milk production, DMI, and production efficiencies were observed when cows consumed the TMR diet compared with the grazing diets. Greater energy (P<0.001) was available for milk production after maintenance for the TMR treatment. All treatments had similar energy (148.64 g Unité fourragère lait; UFL) available for milk solids (MS) production after accounting for maintenance. Cows consuming the TMR diet had significantly higher (P<0.001) daily energy intake (+17%) compared to the pasture-fed cows. Cows grazing the CL swards consumed 1.03 kg greater (P<0.001) total DMI compared to the GR cows. This translated into greater daily milk (+1.2 kg) and MS (0.12 kg) compared with the GR treatment. The current study highlights the benefits of a TMR and ryegrass/white clover diet for increasing milk production, and energy efficiencies above a grass-only diet.

Introduction
Typically, pasture based systems of milk production are characterised by moderate levels of milk productivity, high profitability per kg of milk produced (Dillon et al., 2005; Peyraud et al., 2010; Lorenz et al., 2019). While, confinement systems, feed a well-balanced TMR diet which has the potential to maximise milk production and the option to adjust the diet to meet the cows nutritional requirements depending on age, stage of lactation, etc. (Kolver and Muller, 1998; Bargo et al., 2002). In pasture based dairy systems, one of the main limiting factors for milk production is low DMI (Bargo et al., 2003). In contrast, feeding dairy cows a TMR diet, composed of a mix of grass/maize silage, carbohydrates and concentrates supports higher milk production per cow through increased daily DMI and greater control of feed intake quality (Charlton et al., 2011). Differences in energy maintenance requirements associated with walking and grazing activity and intake of nutrients (Bargo et al., 2002; Kolver and Muller, 1998) are the main factors limiting DMI and constraining milk production of pasture-based cows versus cows in a TMR based system. Including forages such as white clover in the herbage offered to dairy cows, is an opportunity to increase productivity levels and energy efficiency in grass-based dairy production systems. Therefore, the objective of this study was determine the influence of feeding a grass-only, grass-white clover or TMR diet on DMI, milk production and metrics of production efficiency..

Methods
A full lactation farm systems experiment was carried out at Teagasc, Moorepark, Fermoy, Co. Cork, Ireland (52°16′N; 8°25′W; 49 m above sea level) from February to November over seven lactations (2015-2021). Each year, a total of 54 primiparous and multiparous spring calving dairy cows were selected randomly and allocated

to one of three treatments based on calving date (16th February ± 5.3 days), 2 week pre-experimental milk yield (24.2 ± 1.99 kg), 2 week pre-experimental MS yield, and lactation number (2.8 ± 0.26). The three treatments were: TMR, grass-only (GR) and grass-white clover (CL). For the entire lactation cows consuming the TMR diet were housed in cubicle accommodation as one group and were fed concentrate, maize (Zea mays L.) silage and grass silage to achieve a daily target intake of 22.9 kg DM/d on average, over the seven years of the experiment using electronically controlled Roughage Intake Control feeders (Hokofarm Group B.V., Marknesse, the Netherlands). The composition of the TMR changed throughout the duration of the experiment depending on the nutritive value of the maize and grass silage. The TMR was fed ad libitum with at least 10% feed refusals daily. Each morning the refusals were removed from the feeders and new feed was mixed during the morning milking, and fed using a Keenan diet feeder (Keenan, Boris, Carlow, Ireland). The GR swards were a 50:50 perennial ryegrass (*Lolium perenne* L.) mixture of 'AstonEnergy' (tetraploid) and 'Tyrella' (diploid) sown at 27 kg/ha. The CL swards contained the same PRG mixture plus a 50:50 blend of the medium leaf sized white clovers 'Chieftain' and 'Crusader'. The GR and CL swards received 250 and 150 kg N/ha, respectively.

The target pre-grazing herbage mass was 1300-1500 kg DM/ha and the target post-grazing sward height was 4 - 4.5 cm. The GR and CL cows received a daily herbage mass of 17 kg DM and an individual concentrate allowance of 1 kg per day, fed in the parlour during milking time. Both pasture-based treatments were stocked at 2.74 cows/ha. White clover content was measured for the CL paddocks prior to each grazing using the method as described by Egan et al. (2018).

Dry matter intake was estimated in May, July and September each year throughout the study using the n-alkane technique for the GR and CL treatments. The electronic roughage intake control system recorded the fresh weight of the TMR consumed daily by each cow and the DMI was calculated by measuring the DM of a subsample of the diet consumed. Simultaneously, during the DMI estimation periods, milk production, production efficiencies and bodyweight were also measured. Milk yield was recorded automatically daily (Dairymaster, Causeway, Co. Kerry, Ireland) and milk composition (fat and protein) was measured weekly from a successive evening and morning milking using infrared spectrophotometry (MilkoScan 203, Foss Electric, Hillerød, Denmark). The production and energetic efficiencies (as per INRA 2010) examined were UFL available for milk production after accounting for maintenance, UFL required per kg of MS, and UFL intake per kg of MS after accounting for maintenance. Bodyweight was measured weekly using an electronic portable scale and Winweigh software package (TRU-test Limited, Auckland, New Zealand). Data were analysed in SAS using Proc Mixed. Terms for treatment, year, calving date, parity, measurement period and associated interactions were included in the model.

Results and Discussion

Mean average daily milk and MS yield was significantly greater ($P < 0.001$) when cows consumed a TMR diet compared with the GR or CL diets (Table 1). This can likely be attributed to the higher and more consistent quality of the nutritionally balanced TMR diet compared with pasture-based diets, where the nutritive value of grass varies depending on stage of growth, time of year, DM content, and sward composition (Hennessy et al., 2020). With an average white clover proportion of 29.3% in the botanical composition of the pasture, cows on the CL treatment produced an extra ($P < 0.001$) 0.12 kg of MS compared with the GR cows. Kolver and Muller, 1998, determined that 60% of the difference in milk production between cows consuming TMR versus cows consuming herbage can be explained by difference in DMI. Therefore, in the current study, the greater milk production observed for the TMR and CL over the grass-only diet is likely a reflection of DMI and energy intake. Cows on the TMR and CL treatments had a 17 and 6%, respectively, greater DMI compared with that of the cows consuming the GR diet. This result is as expected due to the experimental design of the study. The TMR treatment was offered a daily DMI of 22.9 kg DM while the GR and CL cows were offered a daily herbage mass of 18 kg DM. However, despite both pasture groups being offered similar daily herbage mass, the greater DMI noted for the CL group compared to the GR group occurred as a result of the lower ($P < 0.001$) post-grazing sward height observed for the CL swards compared with the GR swards (4.06 vs. 4.18 cm). It is also well reported in the literature that cows grazing grass-white clover swards can achieve a greater DMI due to a grazing preference for white clover and a faster rate of rumen passage (Egan et al., 2018). It was noted that BCS was greatest ($P < 0.001$) for the cows on the TMR, compared to the GR and CL cows, which did not statistically differ from each other (3.11 vs. 3.02 units). These differences in BCS can be most likely be explained the significantly lower energy intake of the pasture-based cows versus the TMR cows (17.88 vs. 20.30 Unité fourragère lait (UFL); Table 1) and higher energy intake requirements associated with grazing and waling activities (Bargo et al., 2002).

The results of the current study indicates that the cows consuming the TMR diet supported greater production and energetic efficiencies compared with the pasture-based treatments (Table 1). The UFL available for milk production was greatest ($P < 0.001$) for the TMR treatment, intermediate for the CL, and lowest for the GR treatment. This observation can be explained by the TMR cows consuming the highest total DMI per 100 kg of BW, while the GR cows consumed the lowest. The TMR cows had an additional 12% total energy available for MS production, compared with the pasture-base treatment which did not differ from each other. Notably, all three diets supported the same energy available for MS production when maintenance energy had been accounted for. The ability to achieve high quantities of DMI per unit of BW, and efficiently convert this feed into MS is a vital metric of intensive dairy production (Buckley et al., 2005). Thus, this study highlighted the potential of feeding a TMR diet or incorporating clover into the sward for improving energy efficiency and maximising the genetic potential of dairy cows above that of a grass-only diet.

Table 1. Comparison of milk production performance, total DMI, energy intake, and production efficiencies for cows consuming TMR and pasture-based diets.

	Diet[1]				*P*-value		
	GR	CL	TMR	S.E.	Diet	Period	Diet × Period
Milk Yield (kg/day)	19.3[a]	19.6[a]	25.5[b]	0.43	<0.001	<0.001	<0.001
Milk fat (%)	4.66[a]	4.7[ab]	4.81[b]	0.056	<0.05	<0.001	NS
Milk protein (%)	3.67[a]	3.69[a]	3.60[b]	0.022	<0.001	<0.001	<0.001
Milk solids yield (kg/day)	1.56[a]	1.68[b]	2.04[c]	0.023	<0.001	<0.001	<0.001
TDMI[2] (kg/day)	16.27[a]	17.29[b]	19.58[c]	0.233	<0.001	<0.001	<0.01
Energy Intake (UFL[3]/day)	17.37[a]	18.39[b]	20.30[c]	0.242	<0.001	<0.001	<0.01
Bodyweight	524.6[a]	524.8[a]	553.4[b]	5.38	<0.001	<0.001	<0.05
TDMI (kg/100 kg of BW[4])	3.19[a]	3.35[b]	3.60[c]	0.042	<0.001	<0.001	<0.05
UFL available for milk after maintenance	10.73[a]	11.68[b]	14.04[c]	0.184	<0.001	<0.001	<0.001
Milk solids (g/UFL of NEI[5])	91.46[a]	92.79[a]	102.75[b]	1.134	<0.001	<0.001	<0.001
Milk solids/UFL available after maintenance (g)	149.52	146.23	150.17	2.22	NS	<0.05	<0.001

[1]Diets: GR = grass-only swards; CL = grass-white clover swards; TMR = total mixed ration
[2]TDMI = Total dry matter intake
[3]UFL = Unité fourragère lait
[4]BW = bodyweight
[5]NEI = Net energy intake
[a-c] Means bearing different superscript within a row differ significantly (P<0.05)

Conclusions and/or Implications

Diet had a significant effect on milk production, DMI, and production efficiency. Feeding a fully nutritionally balanced TMR diet can significantly increase milk production due to greater energy intake and greater energy available for milk production after accounting for maintenance. White clover is also an important tool which can be effectively sown with PRG to improve the efficiency of pasture-based dairy production. Thus, when a similar cow type is used, feeding a TMR or incorporating white clover can effectively be incorporated into intensive milk production systems to enhance milk production over that of a grass-only diet. Further examination of the environmental implications of each feeding regime warrants further research.

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