Effect of dietary forage proportion and crossbreeding on dairy cows' feeding efficiency and methane emissions



Sabrina Ormston[a], Tianhai Yan[b]*, Xianjiang Chen[b], Alan W. Gordon[c], Katerina Theodoridou[d], Sharon Huws[d], Sokratis Stergiadis[a]*.

[a]University of Reading, United Kingdom. [b]Agri-Food and Biosciences Institute, United Kingdom. [c] Agri-Food and Biosciences Institute, Statistical Services, United Kingdom. [d]Queen's University Belfast,United Kingdom.

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Feeding dairy cows

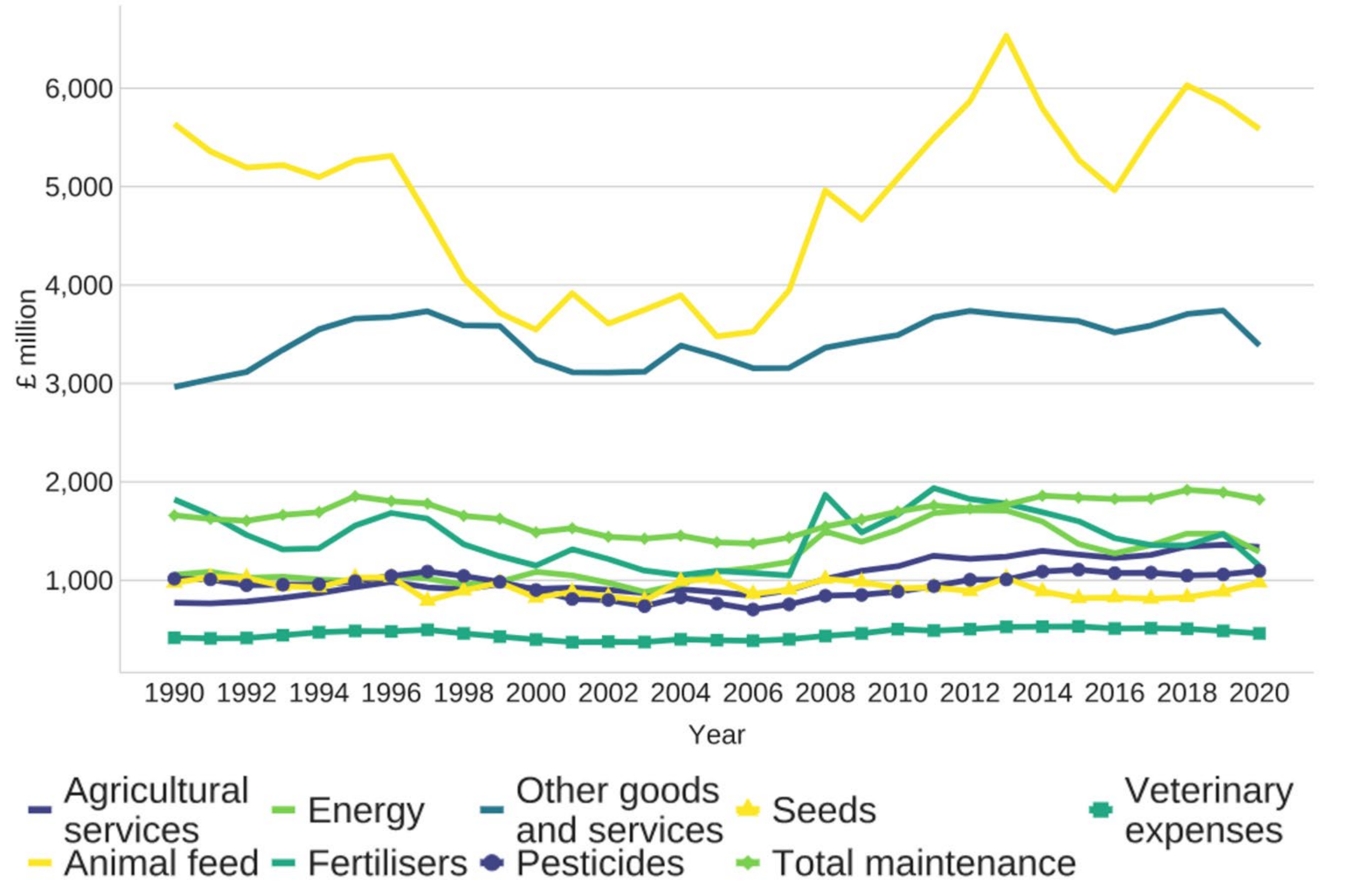

Figure 1: UK Principal farm costs

DEFRA, (2023) United Kingdom Food Security Report 2021: Theme 2: UK Food Supply Sources

- 11.9 million tonnes of wheat, barley, and oats.
- Accounts for over 60% of UK grown grain.
- The most expensive and volatile input across the whole of the agricultural sector.
- Cost was £5,586 million in 2020.

Increasing forage proportion

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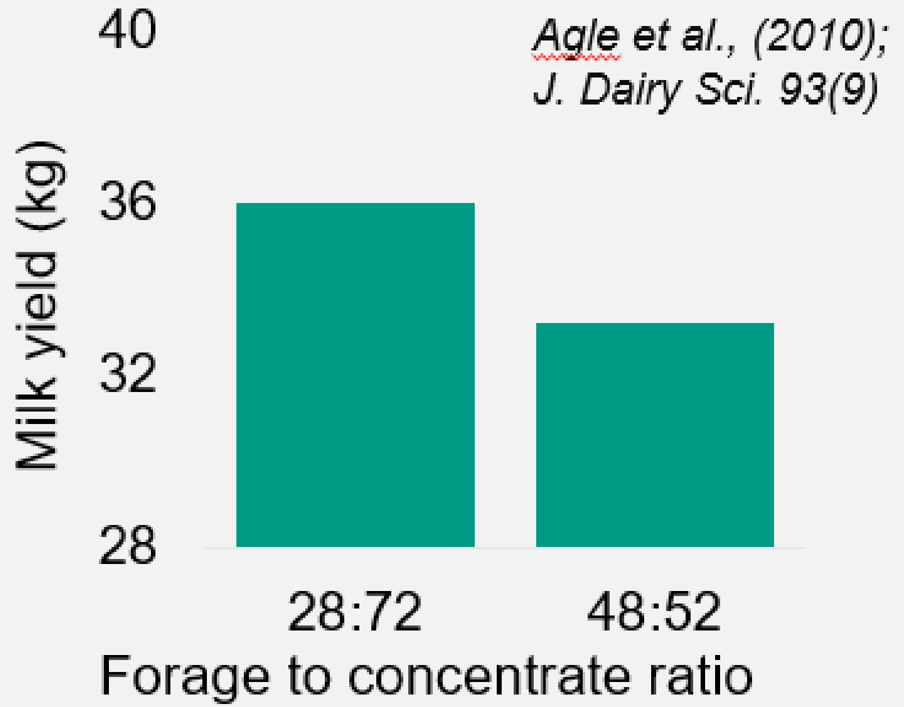

Figure 2: Impact of F:C on Milk yield

- Milk yield is reduced as F:C increases
- Feed efficiency is also often reduced as F:C increases

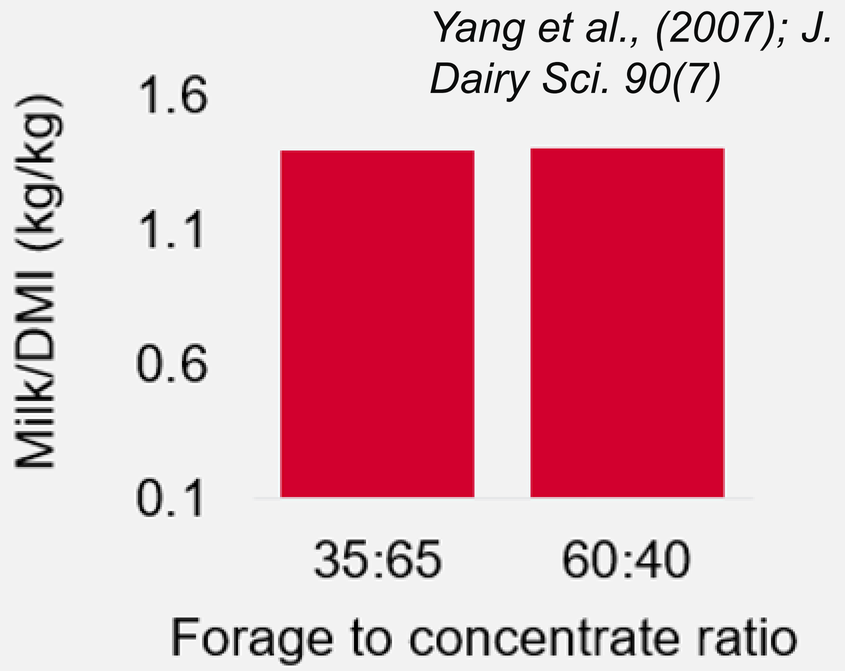

Figure 3: Impact of F:C on fat corrected milk / DMI

Some studies suggest that modest increases could improve feed efficiency by reducing DMI

F:C = forage to concentrate ratio; DMI = dry matter intake.

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Increasing forage proportion

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Aguerre et al., (2011); J. Dairy Sci. 94(6)

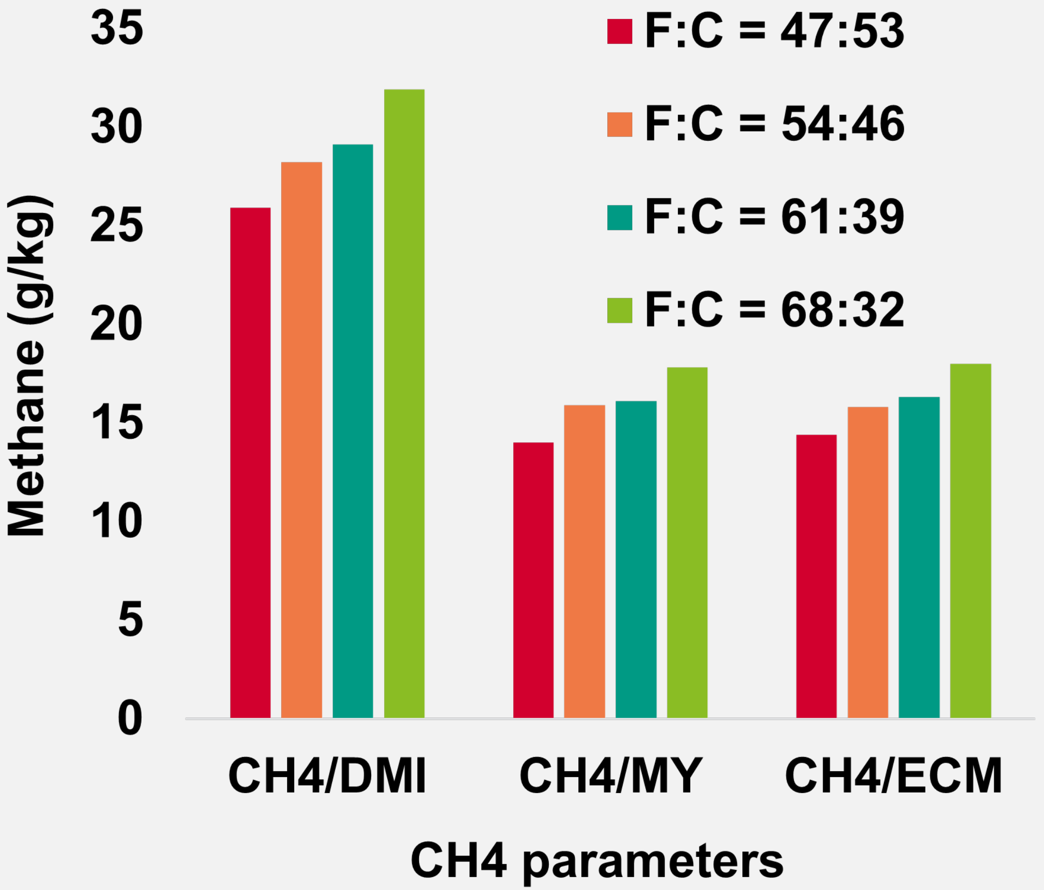

Figure 4: Impact of F:C on CH_4 production parameters

- Increasing dietary forage may also increase CH_4/DMI and CH_4/milk yield.
- Feeding concentrates has been a strategy to mitigate CH_4 emissions by reducing CH_4 /DMI CH_4/Milk yield
- CH_4 per kg of DMI per kg of MY and ECMY was highest in diets containing 68% compared to 61, 54 and 47% F:C.

F:C = forage to concentrate ratio; CH_4= methane; DMI = dry matter intake; MY = milk yield; ECMY = energy corrected milk yield

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Study aims

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The aim of this study was to:

- Investigate the impact of forage proportion (**FP**) and breed on productivity (milk yield, ECMY), feed efficiency, and CH_4 emissions parameters
- Identify potential FP levels for optimum performance and reduced CH_4 emissions, using linear and quadratic regression models.

FP = forage proportion; CH_4= methane

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Materials and Methods

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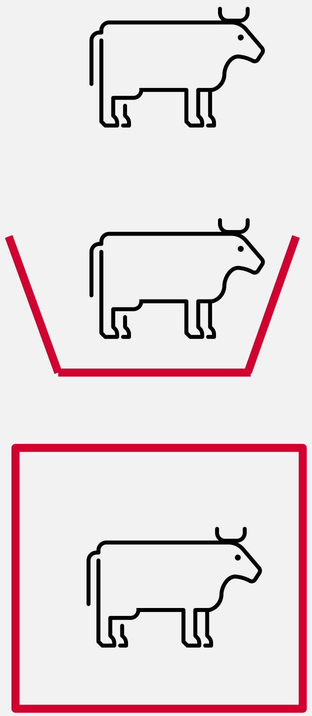
Data and animals

- Data from 32 cow metabolism studies
- 796 Holstein-Friesian cows (**HF**)
- 50 Norwegian Red cows (**NR**)
- 46 Jersey x HF (**J × HF**) crossbred cows
- 16 Norwegian red x HF (**NR × HF**) crossbred cows

Cow diets

- Forage only (n=65)
- Varying proportions of forage and concentrate (n=843)



Experimental diets for at least 3 weeks

Digestibility stalls 5-8 days

Respiration calorimeter chambers 3-5 days

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Statistical analysis

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- Data were separated into 4 groups based on forage proportion **(FP)**:

  - Low (**LFP**; 10% to 30%, n=40)
  - Medium (**MFP**; 30% to 59%, n=551)
  - High (**HFP**; 60% to 87%, n=243)
  - Pure (**FOR**; 100%, n=65) FP.

Statistical analysis

- GenStat (23^{rd} edition)
- Linear mixed model (residual maximum likelihood analysis; **REML**)
- Fixed effects: FP (LFP, MFP, HFP and FOR) and breed
- Random: experiment and cow (nested in experiment)
- Pairwise comparisons using Fisher's LSD test

LFP	MFP	HFP	FOR
10-30%	30-59%	60-87%	100%
n = 40	n = 551	n = 243	n = 65

Regression equations

- FP (expressed as % DM) was the explanatory variable
- Response variables: productivity, feed efficiency and CH_4 parameters
- Random effects: cow, experiment, forage proportion, breed, forage type and parity

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Results: Diet

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Table 1. Means ± SE and P-values for the effect of dietary FP on diet composition and feed intake

	LFP	MFP	HFP	FOR	P-value
Diet chemical composition (kg/kg of DM)					
GE content (MJ/kg)	18.5	18.4	18.5	18.8	0.317
ME content (MJ/kg)	**12.1**^{ab}	**11.9**^{ab}	11.6^{b}	11.0^{b}	<0.001
CP	**0.20**^{a}	**0.19**^{a}	0.17^{b}	0.16^{b}	<0.001
ADF	0.21^{c}	0.21^{c}	0.27^{b}	**0.31**^{a}	<0.001
NDF	0.36^{c}	0.37^{c}	0.46^{b}	**0.54**^{a}	<0.001
Total DMI (kg/d)	**17.3**^{a}	**17.9**^{a}	15.3^{b}	13.8^{b}	<0.001
CP intake	**3.42**^{a}	**3.40**^{a}	2.66^{b}	2.36^{b}	<0.001
ADF intake	3.65^{b}	3.82^{ab}	4.09^{b}	4.22^{ab}	<0.001
NDF intake	6.29^{c}	6.50^{c}	7.09^{b}	7.51^{a}	<0.001

FP = forage proportion, LFP = low forage proportion (10 – 30% DM), MFP = medium forage proportion (30-59% DM), HFP = high forage proportion (60 – 87% DM), FOR = pure forage (100% DM), GE = gross energy, ME = metabolizable energy, CP = crude protein, ADF = acid detergent fibre, NDF = neutral detergent fibre

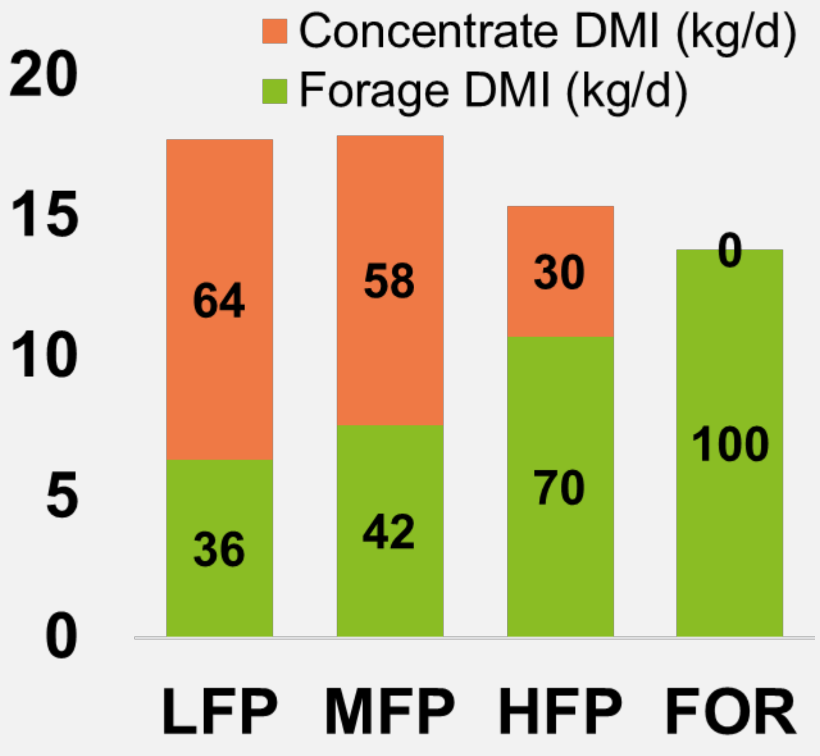

Figure 5: Proportions of forage and concentrate DMI (kg/d)

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Results: Productivity and feed efficiency

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Table 2. Means ± SE and P-values for the effect of dietary FP on productivity and feed efficiency

	LFP	MFP	HFP	FOR	P-value
Milk production (kg/d)					
Milk Yield	**25.0^{a}**	**22.6^{a}**	17.5^{b}	11.9^{b}	<0.001
ECMY Yield	**25.1^{a}**	**23.6^{a}**	18.3^{b}	12.7^{c}	<0.001
Feed efficiency (kg/kg)					
Milk yield/DMI	**1.40^{a}**	**1.26^{a}**	1.15^{b}	0.89^{b}	<0.001
ECMY/DMI	**1.43^{a}**	**1.32^{a}**	1.20^{b}	0.95^{b}	<0.001
Milk yield/Forage DMI	5.33^{a}	3.21^{b}	1.72^{c}	0.77^{d}	<0.001
Milk yield/Concentrate DMI	2.05^{b}	2.09^{b}	4.09^{a}	*	<0.001

FP = forage proportion, LFP = low forage proportion (10 – 30% DM), MFP = medium forage proportion (30-59% DM), HFP = high forage proportion (60 – 87% DM), FOR = pure forage (100% DM), DMI = dry matter intake, ECMY = energy corrected milk yield.

- Milk yield and ECMY were higher in LFP and MFP compared to HFP and FOR
- Milk yield/DMI and ECMY/DMI were higher in LFP and MFP compared to HFP and FOR
- Milk yield/forage DMI decreased with increasing FP
- Milk yield/concentrate DMI increased with increasing FP
- No difference in Milk yield, Milk yield/DMI and ECMY/DMI between HFP and FOR

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Results: Productivity and feed efficiency

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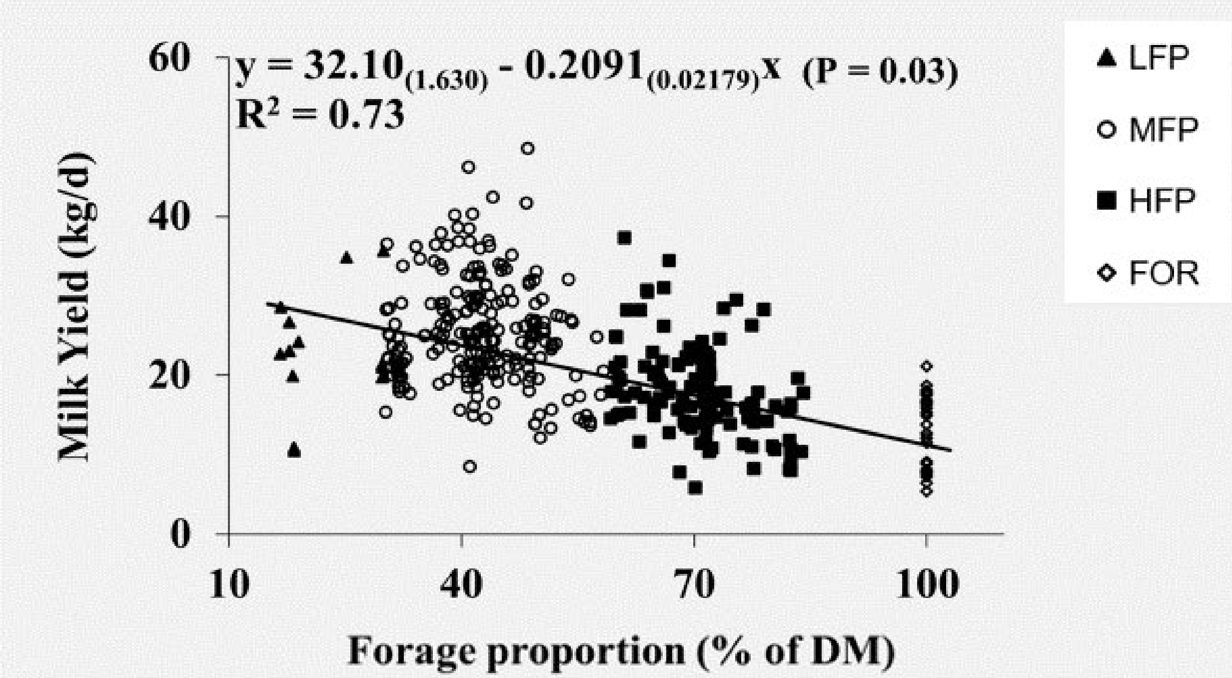

Figure 6: Relationship between FP (%) and milk yield

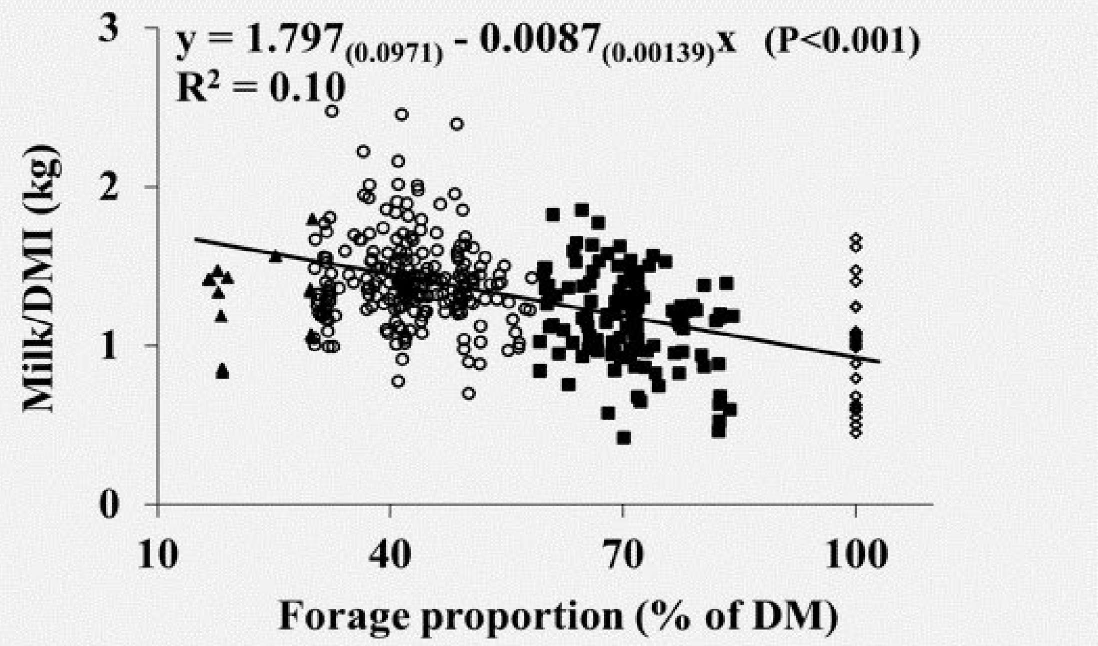

Figure 7: Relationship between FP (%) and milk/DMI

- Linear reductions in milk yield with increasing FP, with milk yield decreasing by **0.21 kg/d with each 1% increase in FP**
- Linear reductions in milk/DMI with increasing FP, with milk/DMI decreasing by **0.09 kg/d with each 1% increase in FP**

FP = forage proportion; DMI = dry matter intake; LFP = low FP; MFP = medium FP; HFP = high FP; FOR = 100% FP

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Results: Methane parameters

Table 1. Means ± SE and P-values for the effect of dietary FP on productivity and feed efficiency					
	LFP	**MFP**	**HFP**	**FOR**	**P-value**
Methane parameters					
CH_4 (g/d)	384^{ab}	**397^{a}**	371^{b}	316^{b}	<0.001
CH_4/DMI (g/kg)	22.5^{ab}	22.4^{b}	**24.3^{a}**	22.9^{ab}	<0.001
CH_4/Milk Yield (g/kg)	21.0^{ab}	19.1^{b}	**22.5^{a}**	**27.0^{a}**	<0.001
CH_4/ECM (g/kg)	21.1^{ab}	17.9^{b}	**21.6^{a}**	**25.8^{a}**	<0.001

LFP = low forage proportion (10 – 30% DM), MFP = medium forage proportion (30-59% DM), HFP = high forage proportion (60 – 87% DM), FOR = pure forage (100% DM), ECM = energy corrected milk, CH_4 = methane

- MFP had the highest CH_4 production (g/d) but did not differ to LFP.
- HFP produced the most CH_4/DMI (g/kg).
- HFP and FOR produced the most CH_4/Milk Yield and CH_4/ECM (g/kg) but did not differ from LFP.

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Results: Methane parameters

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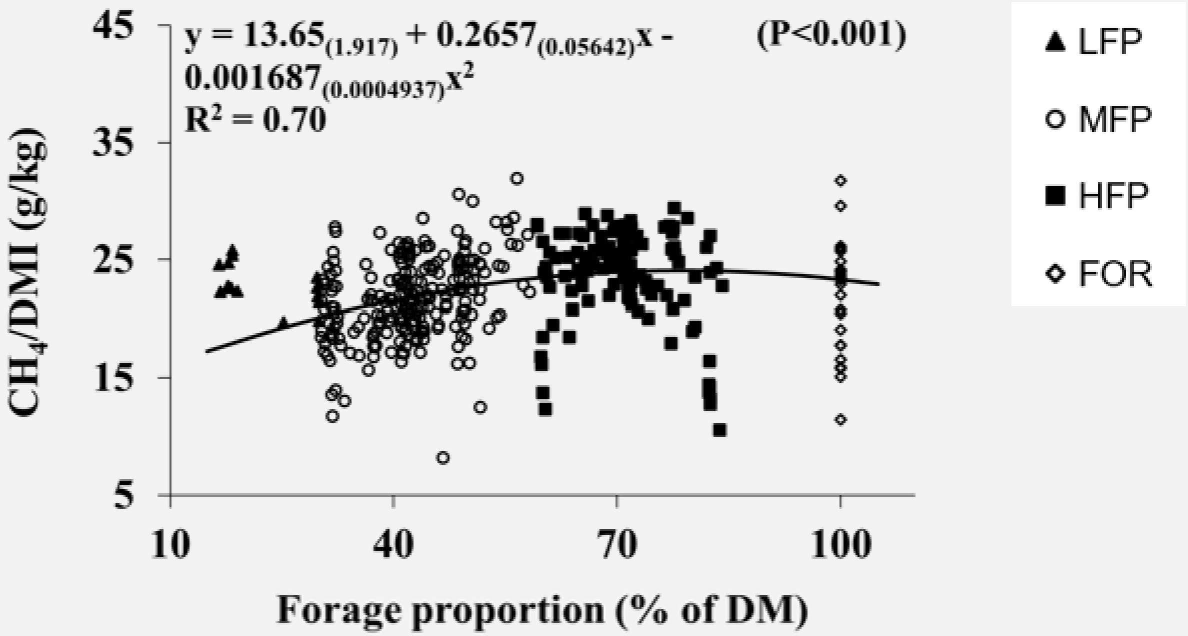

Figure 8: Relationship between FP (%) and CH_4/DMI

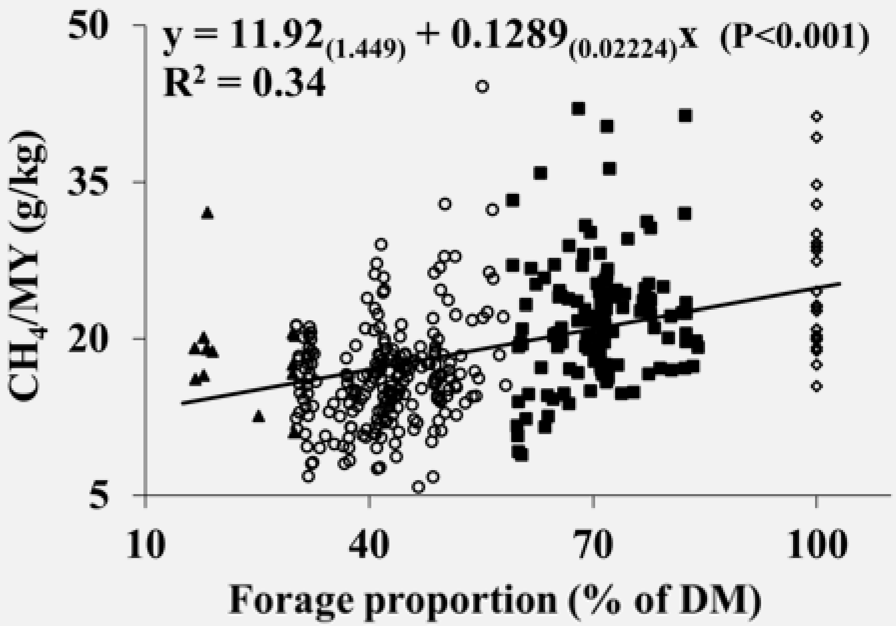

Figure 9: Relationship between FP (%) and CH_4/MY

- CH_4/DMI continues to increase between FP 15 – 75%, after which, CH_4/DMI reduced.
- CH_4/Milk yield increases by 1.2 g/kg with each 10 % increase in FP.

FP = forage proportion; DMI = dry matter intake; LFP = low FP; MFP = medium FP; HFP = high FP; FOR = 100% FP; CH_4 = methane; MY = milk yield

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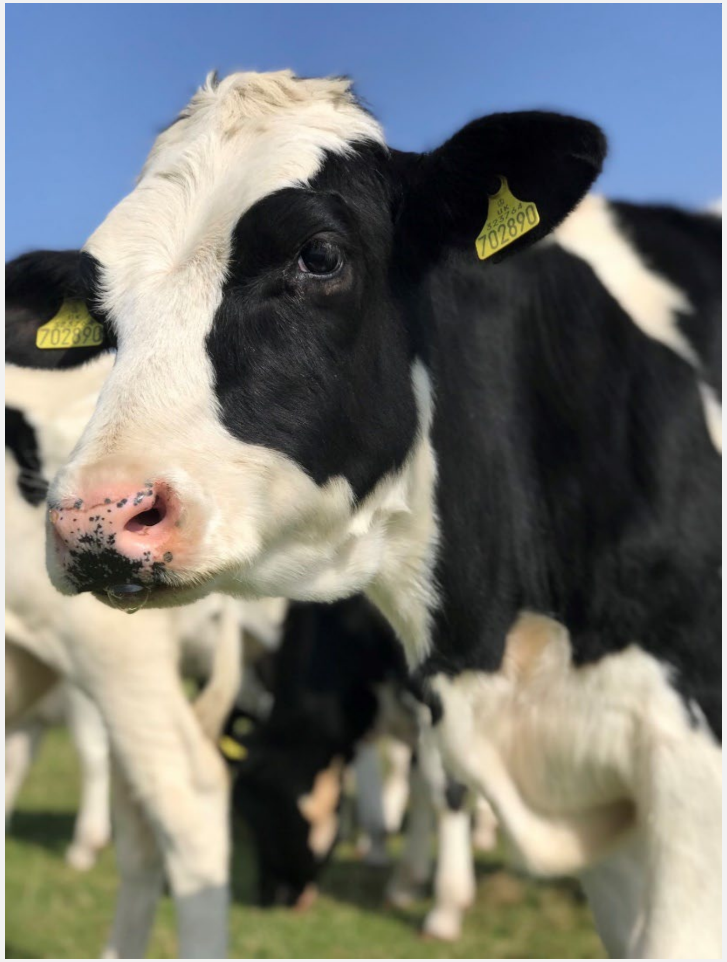
Conclusion

- A reduction in dietary FP from 60-87% to 30-59%, improved productivity and feed efficiency and reduced CH_4 yield and intensity.
- Regression analysis suggested there was a peak for CH_4/DMI at 75% FP.
- Further reduction in dietary FP to 10-30% did not result in further improvements.
- Milk yield and feed efficiency were similar between diets with 60-87% and 100% FP.
- It may be economically beneficial for pasture-based low-input systems (characterised by high forage feeding), to adopt a high-forage diet



FP = forage proportion; DMI = dry matter intake; CH_4 = methane

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