MM32: Precision Feeding

Category
Livestock management: Increased NUE and improved feeding practices

Overview
Precision feeding provides opportunities for reducing the feed conversion ratio of animals, and thereby the emissions from feed production. It can also reduce the rate of N (and volatile solid) excretion and therefore the N2O and CH4 emissions arising during manure management. Applicable primarily to housed animals (i.e. pigs and dairy/beef cattle during the housed period) that can be weighed at regular intervals, and the information used to adjust rations, i.e. dairy cattle and pigs. Hristov et al (2013, p60) summarise it thus:

"Precision feeding, i.e. closely matching animal requirements and dietary nutrient supply, is important for maximizing feed utilization, stabilizing rumen fermentation, improving rumen and animal health, and minimizing nutrient excretion in manure. These effects of precision feeding are expected to decrease enteric and manure GHG emissions. Accurate feed composition analyses are an integral part of precision feeding but require infrastructure and investment, which may not be available in many production systems."

Mitigation summary

Effect on GHG categories*	Rating	Notes
Enteric CH_4	-	
Manure CH_4	-	
Manure N_2O	-	
Soil N_2O: applied N	-	
Soil N_2O: grazing		
Energy CO_2: fieldwork	-	
Energy CO_2: other		
CO_2 liming and urea		
CO_2 sequestration below ground		
CO_2 sequestration above ground		
Pre-farm emissions	-	
Post-farm emissions		
Substitution of higher C products		
Production increases by more than the emissions		
Confidence in mitigation effect	moderate	
Cost-effectiveness**	low?	
Confidence in cost-effectiveness	low	

* "-" GHG reduction, "+": GHG increase, " ": no significant effect
** low: =< £0/tCO_2e, moderate: £0/tCO_2e< >SCC, high: >SCC

Related measures and potential synergies

Measure	Impact on other measures
21 Higher sugar content grasses	
24 New low-emission livestock housing systems	
25 Covering slurry	
31 High starch diet	

Inclusion in other marginal abatement cost curves

UK 2008	UK 2010	UK 2015	Ireland 2012	France 2013	France 2019
n	n	Precision livestock farming	n	y	?

What does the measure entail?

Matching the diet more closely to the animal's nutritional requirements. For pigs this may involve regular weighing of animals and adjustment of the ration protein content based on weight and growth rate, and supplementation of diets with synthetic amino acids. For ruminants, emissions could be reduced through improved characterisation of forages to enable appropriate supplementation.

"Accurate analysis of feed composition is the first step in the precision feeding process. Even in developed countries with established feed analysis networks, there is still substantial variability in feed analysis among commercial laboratories (Hristov et al., 2010a; FAO, 2011b). In intensive dairy systems, for example, day in and day out control of forage, particularly silage DM, can have a profound effect on precision feeding of the cow for maximum production and profitability." Hristov et al. (2013, p59).

Feed analysers based on near-infrared reflectance spectroscopy (NIRS) technology can measure the nutritional content and automatically adjust the ration composition. "Such precision in mixing feed ingredients on the farm, although perhaps not refined yet and not practical for many production systems, should produce a consistent diet and result in increased milk production and greater feed efficiency, which will eventually translate into optimal rumen function, animal health and longevity." Hristov et al. (2013, p59).

Eory et al. (2015) "For dairy cattle, precision feeding opportunities lie in the capacity to offer individually tailored supplements to cows in out of parlour feeders (which have been available for over 30 years using neck based transponders) or to individual cows in standard milking parlours, or through automated milking systems (milking robots). Combining milk recording and automated weighing systems with milking parlour visits provides good data on which to provide tailored supplement levels. Hills et al. (2015), in a comprehensive review of individual feeding of pasture based dairy cows, however, highlights the complexity in determining responses to supplementary feeds and provided compelling evidence that both cow-level (e.g. genotype, parity, days in milk, cow body weight, condition score, feed intake) and system-level (e.g. pasture allowance and other grazing management strategies and climate) parameters can influence the marginal milk production response to supplementary feeding. Basically, the responses are likely to be system and farm specific."

Abatement rate

Pomar et al. (2011) found that growing pigs with daily tailored diets had nitrogen intake reduced by 25% and N excretion reduced by more than 38%.

Cherubini et al. (2015) showed that pig diets low in protein had improved carbon footprints, principally through lower need for imported soya.

The 2015 UK MACC (Eory et al. 2015) had the measure "Improving beef and sheep nutrition", which involved improving animal performance and reducing methane yield via improvement of ration nutritional values (i.e. digestibility of the ration). This was achieved by getting advice from an animal nutritionist to improve the composition of the diet, complemented with forage analysis and improved grazing management.

Eory et al. (2015) assumed that improved diet formulation and grazing management increases the digestibility of the roughage and concentrate by 2% from their original values (i.e. from 70% to 71.4%), and results in a 2% improvement in growth rates.

2035, MTP (no interactions) 148ktCO2e -26£/tCO2e

"The sensitivity analysis showed that the abatement potential (without interactions, 2035, UK, CFP, d.r. 3.5%) varied between 44 and 89 kt CO2e y-1; this analysis involved changing the assumptions on uptake, change in the digestibility of the feed materials, change in yield, costs of the measure and the prices of livestock products" Eory et al. (2015, p92)

Martineau et al. (2016) suggest a median abatement potential for Optimised feeding strategies for livestock of 40ktCO2e/year.

Defra (2012, p33) MTP (ktCO2e) England

Farmscoper ID	Measure	Abatement potential (ktCO2e)	£/tCO2e
331	Reduce dietary N and P intakes: Dairy	112	472
332/3	Reduce dietary N and P intakes: Pigs and poultry	21	269
34	Adopt phase feeding of livestock	11	538

Farmscoper - % reduction in pollutant flows (ADAS 2017)

ID		Methane	N2O - direct	N2O - indirect
331	Reduce dietary N and P intakes: Dairy	2	2	2
332	Reduce dietary N and P intakes: Pigs	2	2	10
333	Reduce dietary N and P intakes: Poultry	2	2	10
34	Adopt phase feeding of livestock	2	2	2

Applying the % reductions in the above table to the dairy, pig and poultry emissions in the 2018 suggests a maximum abatement potential of around 150ktCO2e/year could be achieved via precision feeding. Note this is for reduced enteric and manure CH4, and manure N2O; it doesn't include the emissions from feed production which are also likely to be reduced.

French 2013 MACC

Pellerin et al. (2013) analysed the extent to which manure N2O emissions could be mitigated by reducing the dietary nitrogen of dairy cattle and pigs, without impacting on the animals' performance.

Reduce the protein content in the diets of dairy cows (reducing cow ration CP content to 14%)

Reduce the protein content in the diets of pigs and sows (two mutually exclusive sub-measures: - (a) generalisation of biphase feeding, with increased use of industrial AAs in place of soybean meal;(b) development of multiphase feeding with use of synthetic AAs.

Measure	Reduction in manure N2O (kgCO2e/animal/year)	Reduction in feed emissions (kgCO2e/animal/year)	Cost-effectiveness (€/tCO2e)
Reduce dairy cow CP	70-124	171	-94
Pig biphase	276-510	306	-97
Pig multiphase	381-692	374	-75

Cost-effectiveness

Pomar et al. (2011) found that feed cost was 10.5% lower for pigs fed daily tailored diets.

Andre et al (2010) found that tailoring feeding to the individual dairy cow led to a 10% increase in profit margins by increasing concentrate supplementation and milk yields.

Defra (2012) reported high costs (i.e. > SCC) for reducing dietary N and P intakes and adopting phase feeding (Annex C).

Pellerin et al. (2013, p4) suggest that it could be cost saving.

ADAS (2017)

	Capital Cost (£)	Operational Cost (£)	Cost (£/m3 manure)
Reduce dietary N and P intakes: Dairy	0.00	0.76	0.76
Reduce dietary N and P intakes: Pigs	0.00	2.59	2.59
Reduce dietary N and P intakes: Poultry	0.00	6.39	6.39
Adopt phase feeding of livestock	0.94	-3.81	-2.87

Phase feeding - change between Defra (2012) (based on the earlier version of Farmscoper) which gave a high cost and ADAS (2017) which indicates a negative cost.

Applicability, current uptake and potential additional maximum uptake

% of UK farms implementing measure (ADAS 2017)

	Implementation rate (%)		
	Prior	Maximum	Additional
Reduce dietary N and P intakes: Dairy	10	100	90
Reduce dietary N and P intakes: Pigs	80	100	20
Reduce dietary N and P intakes: Poultry	80	100	20
Adopt phase feeding of livestock	80	100	20

Pellerin et al. (2013) reported the maximum technical potential applicability:

- 52% of dairy cows
- 20% additional uptake of biphase
- Almost all pigs could uptake multiphase (currently 0% adopt)

The estimated the annual AP for manure N2O to be:

Dairy cows	0.13-0.23MtCO2e
Pigs biphase	0.26-0.77MtCO2e
Pigs multiphase	0.36-1.01MtCO2e

“for pigs and poultry, phase feeding and the use of synthetic amino acids have been widely adopted by producers and future reductions in N excretion are likely to be at the lower end of the ranges cited (5 and 10% for pigs and poultry respectively).” Martineau et al. (2016, p141)

“However, a reduction in nitrogen intake frequently also results in a reduction in milk yield and there is little financial incentive for farmers to reduce the dietary protein content for cows on grass silage based diets (Cottrill et al., 2006) (Method no. 331).

Adoption of phase feeding is believed to be implemented widely in the pig and poultry industry (Cottrill et al., 2006) (Method no. 34). Similarly, the current uptake of phytase supplements that increase the availability of dietary phosphorus is estimated to be already close to the potential as including the enzyme in the diet is cost neutral. Industry sources indicate that phytase is incorporated into approximately 90% of pig diets, 90% of hen feeds and 40% of broiler rations manufactured in the UK (Cottrill et al., 2006) (Method no. 332).” Gooday & Anthony (2015, p46)

Assumptions used in the MACC

- Based on the uptake rates in Pellerin et al. (2013), Martineau (2016) and ADAS (2017), assume maximum additional uptake rates of: 50% for dairy and 10% for pigs and poultry.
- Dairy cows: 2% reduction in methane (enteric and manure) and 2% reduction in manure N_2O (direct and indirect)
- Pigs: 2% reduction in methane (enteric and manure), 2% reduction in manure direct N_2O and 10% reduction in manure indirect N_2O.
- Poultry: 2% reduction in manure methane, 2% reduction in manure direct N_2O and 10% reduction in manure indirect N_2O.
- The evidence on CE is mixed, however reduced feed costs and/or increased output should offset the costs. Assume £-5/tCO_2e, but check cost assumptions and potential additional uptake rates in workshops.

Ancillary effects

Ancillary effects of the operation

Positive effects		**Source**
Off-farm GHG		
Production	Improved animal health and longevity	Hristov et al. (2013, p59)
Adaptation		
Environment		
Negative effects		
Off-farm GHG		
Production		
Adaptation		
Environment	Potential increase in ammonia emissions if it leads to increased housing of cattle	Defra peer review

Identified implementation challenges and barriers

Potential barriers to uptake and key risks/uncertainties

Barrier to uptake	**Source**
Potential significant capital expenditure on equipment to analyse feed, weigh animals and deliver tailored ration.	
Other key risks/uncertainties	

References

ADAS (2017) FARMSCOPER v4.0 (August 2017) FARMSCOPER4_Cost.xl

Andre, G., Berentsen, P. B. M., van Duinkerken, G., Engel, B. and Lansink, A. G. J. M. (2010) Economic potential of individual variation in milk yield response to concentrate intake of dairy cows. The Journal of Agricultural Science 148, 263-276.

Cherubini, E., Zanghelini, G., Tavares, J., Belettini, F. and Soares, S. (2015) The finishing stage in swine production: influences of feed composition on carbon footprint. Environ Dev Sustain 17, 1313-1328.

Defra. (2012). *2012 review of progress in reducing greenhouse gas emissions from English agriculture.*

Paper 3: Analysis London: Defra. Retrieved from https://www.gov.uk/government/publications/2012-review-of-progress-in-reducing-greenhouse-gas-emissions-from-english-agriculture

Gooday, RD., Anthony, SG., Durrant, C., Harris, D., Lee, D., Metcalfe, P., Newell-Price, P., Turner, A. (2015) Farmscoper Extension Defra Project SCF0104 October 2015

Hills, J. L., Wales, W. J., Dunshea, F. R., Garcia, S. C. and Roche, J. R. (2015) Invited review: An evaluation of the likely effects of individualized feeding of concentrate supplements to pasture-based dairy cows. J Dairy Sci 98, 1363-1401.

Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J. & Oosting, S. 2013. Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO2 emissions. Edited by Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar. FAO Animal Production and Health Paper No. 177. FAO, Rome, Italy.

IBERS. (2010). *Ruminant nutrition regimes to reduce methane and nitrogen emissions.* London: Defra. Retrieved from http://sciencesearch.defra.gov.uk/Document.aspx?Document=AC0209_10114_FRP.pdf

IGER (2001) *Cost curve assessment of mitigation options in greenhouse gas emissions from agriculture*. Final Project Report to Defra (project code: CC0209). http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=8018

Martineau et al. (2016)

Pellerin, S., Bamiere, L., Angers, D., Beline, F., Benoit, M., Butault, J. P., Chenu, C., Colnenne-David, C., De Cara, S., Delame, N., Dureau, M., Dupraz, P., Faverdin, P., Garcia-Launay, F., Hassouna, M., Henault, C., Jeuffroy, M. H., Klumpp, K., Metay, A., Moran, D., Recous, S., Samson, E. and Savini, I. (2013) How can French agriculture contribute to reducing greenhouse gas emissions? Abatement potential and cost of ten technical measures, INRA.

Pomar, C., Hauschild, L., Zhang, G. H., Pomar, J. and Lovatto, P. A. (2011) Precision feeding can significantly reduce feeding cost and nutrient excretion in growing animals, In: edited by D. Sauvant, J. Milgen, P. Faverdin, & N. Friggens (ed) Modelling nutrient digestion and utilisation in farm animals, Wageningen Academic Publishers, pp. 327-334.

van Milgen, J., Noblet, J., Dourmad, J. Y., Labussiere, E., Garcia-Launay, F. and Brossard, L. (2012) Precision pork production: Predicting the impact of nutritional strategies on carcass quality. Meat science 92, 182-187.

Prepared by:	Michael MacLeod, SRUC
Contact:	Michael.Macleod@sruc.ac.uk