9

May
2005

REDUCING ORGANIC NITROGEN OUTPUTS FROM DAIRY COWS AND BEEF CATTLE IN NITRATE VULNERABLE ZONES

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CO-FUNDERS
Department of Agriculture and Rural Development for Northern Ireland

OVERALL SUMMARY OF PROJECT

Dairy cows at grass

The European Union Nitrates Directive, introduced in 1991, aims to prevent the pollution of groundwater and surface water by nitrates arising from agricultural sources. A Northern Ireland-wide (total territory) approach to implementation of the Nitrates Directive was introduced in 29 October 2004 through *"The Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004".* These regulations stipulate the establishment and application of an action programme to regulate farming activities throughout Northern Ireland in order to reduce and prevent water pollution from agricultural sources. The action programme will give statutory effect to a series of measures. One of these proposed measures is to limit the amount of livestock manure that may be applied to land each year to 170 kg organic nitrogen (manure N) per hectare. This limit will have very significant implications for stocking rates on livestock farms in Northern Ireland.

Current values for manure N excretion of livestock within existing NVZ's in Northern Ireland are based on those published in England and Wales (DEFRA, 2002). However, the levels of production achieved from and diets offered to ruminant livestock in Northern Ireland are very different to those in England and Wales. Consequently, the objectives of this research project were to determine the level of manure N output from dairy cows and beef cattle within Northern Ireland. The work consisted of three studies:

1. Prediction of manure N output for dairy cows
2. Prediction of manure N output for beef cattle
3. Investigation of nutritional strategies to improve the efficiency of utilisation of dietary N in milk production

Based on the scientific data presented in the final report, key conclusions of this study in relation to manure N output are summarised below. No account has been taken of nitrogen losses arising from ammonia emissions during grazing, housing, storage or spreading.

- The standard average annual manure N output for dairy cows for Northern Ireland is 91 kg/cow per year, irrespective of live weight and production level.
- The standard annual manure N output of each dairy heifer replacement over 24 months age (500 kg), each suckler cow and each growing and fattening beef animal over 24 months age (500 kg) is 54 kg/animal per year.
- Until a comprehensive dataset for manure N output for lighter weights of cattle in Northern Ireland can be developed, the standard DEFRA N output values for these animals should be used.
- Adoption of milk and beef production systems with lower manure N output should be encouraged through use of lower nitrogen (protein) intakes. Efficient milk production systems can be developed which produce less than 91 kg manure N/cow per year. Derogation to less than 91 kg would require farmers to supply firm evidence (e.g. adequate supporting records) to demonstrate lower manure N output values.

Dairy cows grazing

INTRODUCTION

Large amounts of nitrogen (N) are brought onto farms and much of this remains on the farm rather than being exported in milk, animal tissue or crops. For dairy cows, milk accounts for 25-35 percent of the N consumed. Almost all the remaining N is excreted in faeces and urine (manure). Manure is a major environmental concern due to losses of ammonia to the air and nitrate contamination of surface water and groundwater.

The European Union Nitrates Directive, introduced in 1991, is aimed at preventing the pollution of groundwater and surface water by nitrates arising from agricultural sources. In 2000, the European Court of Justice ruled that the Directive should also apply to eutrophic, or nutrient enriched, freshwaters. Eutrophication arises mainly from excess inputs of N and phosphorus from sources such as farming, sewage and industry. In Northern Ireland, approximately 85% of surface water is eutrophic or likely to become eutrophic. In these circumstances, Member States are required to designate such areas as Nitrate Vulnerable Zones (NVZs). A Northern Ireland-wide (total territory) approach to implementation of the Nitrates Directive was introduced in 29 October 2004 through *"The Protection of Water Against Agricultural Nitrate Pollution Regulations (Northern Ireland) 2004"*. These regulations stipulate the establishment and application of an Action Programme to regulate farming activities throughout Northern Ireland in order to reduce and prevent water pollution from agricultural sources. The Action Programme will give statutory effect to a series of measures. The *"Proposed Action Programme measures for the protection of Northern Ireland's waters"* went to public consultation on 28 February 2005. In line with EU requirements, one of the Action Programme proposals is to limit the amount of livestock manure that may be applied to land each year to 170 kg organic nitrogen (manure N) per hectare.

Clearly this limit will have very significant implications for stocking rates on livestock farms in Northern Ireland. Reducing organic-N output in the manure from dairy cows and beef cattle would be one possibility for reducing N loss to the environment and for maintaining existing stocking rates on dairy and beef farms. Livestock feeding strategies and N management are thus clearly recognised as potential ways of reducing N pollution.

This booklet summarises research undertaken at the Agricultural Research Institute of Northern Ireland (ARINI) in a joint DARD/AgriSearch funded project to examine factors influencing manure N output by dairy cows and beef cattle. The objectives of the project were to collate ARINI data relating to manure N output, to evaluate the effects of diet type on N input, manure N output and animal performance and to develop a model to relate manure N output to diet and animal performance.

This project consisted of three studies:

- Study 1: Prediction of manure N output for dairy cows
- Study 2: Prediction of manure N output for beef cattle
- Study 3: Nutritional strategies to improve the efficiency of utilisation of dietary N in milk production

STUDY 1:

PREDICTION OF MANURE N OUTPUT FOR DAIRY COWS

General summary for Study 1

Two sets of data from lactating dairy cows were collated for development of models to predict manure N output. The first set of data (n = 568) comprised digestibility data from a range of digestibility studies and these were used to develop prediction equations for manure N output. The second set of data (n = 221) comprised production data from four studies of different feeding and management systems (winter indoor feeding and summer grazing vs. indoor feeding for whole lactation). These production data were used to develop prediction equations for total N intake.

It was found from the digestibility data that both live weight and milk yield were poor predictors of manure N output (g/d) (R^2 = 0.22 and 0.32 respectively). There was a very strong relationship between total N intake and manure N output (R^2 = 0.89). Addition of milk yield, live weight and ratio of dietary N against ME contents as supporting predictors of total N intake only had minimal effects on this relationship. Within the data set, there were no great effects of forage type or proportion in diets, animal breed, parity or stage of lactation on the relationship between total N intake and manure N output.

From the production data it was found that there was a strong relationship between milk yield and total N intake (R^2 = 0.77). Adding live weight or metabolic live weight as a secondary predictor for prediction of N intake improved the relationship (R^2 = 0.79).

It was concluded that manure N output could be accurately predicted from total N intake and that total N intake could be accurately predicted from milk yield or milk yield plus live weight. Therefore, the present models can be used to accurately predict manure N output (kg/305 days) for cows with any milk yield between 4000 to 11000 kg and live weight between 400 to 800 kg.

Use of the models to predict manure N output from milk yield and live weight requires two steps:

1. Prediction of total N intake during lactation (kg/305 days) using milk yield and live weight;
2. Prediction of manure N output during lactation (kg/305 d) from the predicted total N intake. This prediction plus the manure N output during the dry period (kg/60 days) is the total manure N output in a year for dairy cows.

Using milk yield data for 2001, these models predict manure N output of 7 to 9 kg/year per cow less in Northern Ireland than in Great Britain.

The average milk yield for 2001 - 2003 in Northern Ireland was 6206 litres over a 305 day lactation with a live weight of 570 kg (Dairy Council, 2004). Using all equations developed in study one of this project gives a mean predicted N intake of 114.2 kg for each 305-day lactation and a mean predicted manure N output of 82.5 kg. This value plus the manure N output of 8.7 kg for the dry period (60 days) gives an average total manure N output of 91 kg/year.

There is, therefore, a strong scientific case for a lower manure N output per cow in Northern Ireland compared to Great Britain. The average manure N output for dairy cows in Northern Ireland is currently 91 kg/cow per year.

Details of Study 1

PREDICTION EQUATIONS FOR DAILY MANURE N OUTPUT

Digestibility data from 568 lactating dairy cows were used to examine relationships between manure N output and animal and dietary variables in order to identify the best variables to use in the development of equations for predicting manure N output. Digestibility experiments are normally only undertaken for a short period (6 days) at various stages of lactation, and consequently the equations developed in this section were derived to predict manure N output on a daily base (g/day). Following extensive examination, total N intake (g/d) was found to be the best predictor for manure N output (g/d). Inclusion of other animal and dietary factors had only a marginal effect on the relationship between manure N output and N intake.

DATASETS

A total of 568 datasets of lactating dairy cows were collated from 26 digestibility studies which were undertaken at ARINI from 1990 to 2002.

The vast majority of data were based on grass silage-based diets (n = 518), while some were derived from fresh grass diets (n = 20) and fodder beet diets (n = 30). The animals used were Holstein cows (n = 539) and Norwegian cows (n = 29).

The 26 digestibility studies collated provided data covering the wide range of dairy systems in Northern Ireland. The range included cow genetic merit (low to high); lactation number (1 to 9), live weight (383 to 781 kg), feed intake (7.5 to 24.3 kg/d of DM), milk yield (6.1 to 49.1 kg/d), diet type (grass silage, fresh grass and fodder beet) and forage DM proportion in the diet (0.21 to 1.00). There was also a wide range in total N intake (155 to 874 g/d), manure N output (130 to 679 g/d) and milk N output (24 to 231 g/d). The data were evenly distributed across the whole range and this, coupled with the wide range and large number of data, enabled accurate statistical analysis.

RELATIONSHIPS BETWEEN MANURE N OUTPUT AND ANIMAL AND DIETARY VARIABLES

Prediction equations for manure N output using total N intake, milk yield and live weight each as a single predictor or in various combinations were developed. The relationship between manure N output and total N intake was very good (R^2 = 0.89) (Figure 1), whilst that with live weight was very poor (R^2 = 0.22). Although the relationship between manure N and milk yield was also poor (R^2 = 0.32), it was better than that with live weight. Using both milk yield and live weight as predictors still gave a much poorer relationship than that with total N intake only (R^2 = 0.47 vs. 0.89). Milk yield, live weight and ratio of dietary N against ME contents (N intake/ME intake) were sequentially added to the relationship between manure N and total N intake.

Although each addition had a significant effect on the relationship ($P < 0.01$ or less), there were only marginal improvements in the overall accuracy of prediction.

In conclusion, total N intake was the best single predictor for manure N output in lactating dairy cows (Figure 1). Addition of other variables (milk yield, live weight, ratio of dietary N against ME contents) resulted in only marginal improvements in the accuracy of prediction.

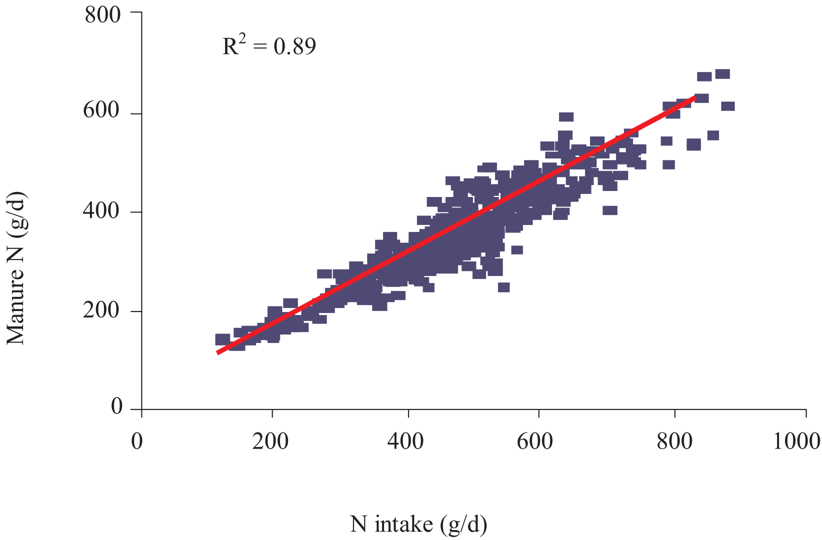

Figure 1 Relationship between manure N excretion (g/d) and N intake (g/d) in lactating dairy cows. (Manure N = 0.713 x N Intake + 4) (Equation 1(a))

PREDICTION EQUATIONS FOR TOTAL N INTAKE DURING LACTATION

In order to develop prediction equations for total N intake during lactation (305 days), data from four feeding experiments undertaken at ARINI were collated. In these experiments, milk yield, live weight and feed intake and dietary N concentration were recorded over a full lactation (Table 2). The four experiments included two different feeding systems: indoor feeding plus grazing (Ferris *et al.,* 2002) and indoor feeding only (Keady and Mayne, 2002 and 2003) (Table 2).

Table 2 The dataset used for developing prediction equations for total N intake in lactating dairy cows

	Mean	s.d.	Minimum	Maximum
Data of Ferris ***et al.*** **(2002) (n=110)**				
N intake (kg/305 d)	143	16.2	111	182
Milk yield (kg/305 d)	7936	1342.7	5461	10853
Live weight (kg)	568	61.4	429	775
Data of Keady and Mayne (2002 and 2003) (n=111)				
N intake (kg/305 d)	125	24.4	81	183
Milk yield (kg/305 d)	7215	1496.3	3420	11376
Live weight (kg)	572	51.8	455	719

Data from the four experiments were combined to develop prediction equations for total N intake over a 305-day lactation for dairy cows. The linear relationship between milk yield and total N intake is presented in Figure 2.

Dairy cows eating silage

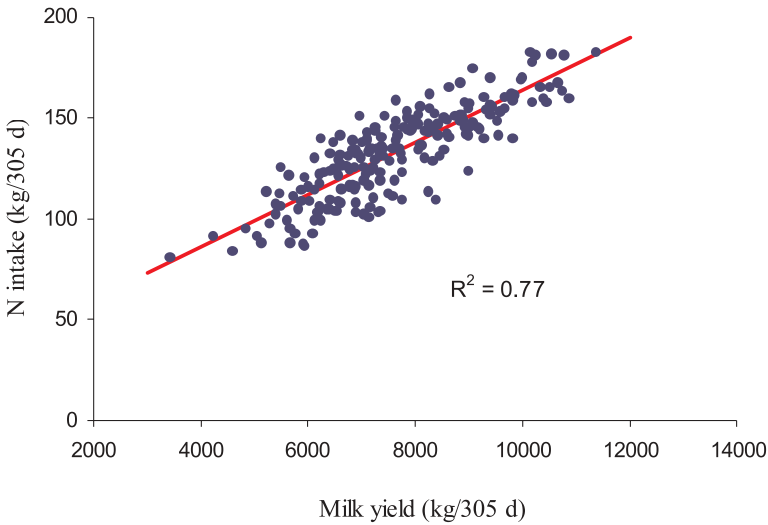

Figure 2 The relationship between milk yield and total N intake using the combined data of Keady and Mayne (2002 and 2003) and Ferris *et al.* (2002)

The equations developed from the combined data to predict total N intake (kg/305 days) from milk yield (kg/305 days), milk yield (kg/305 days) plus live weight (kg) or milk yield (kg/305 days) plus metabolic live weight (kg) are presented in Table 3. All relationships were extremely good (R^2 = 0.77 to 0.79). From these equations, total N intake for a whole lactation (305 days) can be accurately estimated.

Table 3 Prediction equations for N intake (kg/305d) developed from the combined data (n = 221) of Keady and Mayne (2002 and 2003) and Ferris *et al.* (2002) #

	Equations	R^2	
N intake	= 0.0130 (0.0006) MY + 33.8 (4.4)	0.77	(2a)
	= 0.0108 (0.0006) MY + 0.0763 (0.0151) LW + 1.7 (7.7)	0.79	(2b)
	= 0.0108 (0.0006) MY + 0.4951 (0.0982) LW 0.75 - 12.7 (10.2)	0.79	(2c)

# LW = live weight (kg); $LW^{0.75}$ = metabolic live weight (kg);
MY = milk yield (kg/305 days); unit for N intake = kg/305 days

PREDICTION OF MANURE N OUTPUT FOR DRY PERIOD (60 DAYS)

In this project, the manure N excretion for dry dairy cows is estimated from live weight as: manure N (kg/d) = 0.00124 LW $^{0.75}$.

IMPLICATIONS OF THE PRESENT MODELS

The equations presented in Table 3 can be used to estimate total N intake during 305 days of lactation for any milk yield between 4000 and 11000 kg and live weight between 400 and 800 kg. Equation 1(a) (Figure 1) can then be used to estimate manure N output during lactation (305 days). Total manure N output for a year (365 days) can be estimated as:

Total N intake during lactation (kg/305 days)
= Function of milk yield and live weight (Equations (2b) - (2c))

Manure N output during lactation (kg/305 d) (derived from Equation (1a), Figure 1)
= {[Predicted N intake (kg/305 d)/305 * 0.713] + 0.004} * 305

Manure N output during the dry period (kg/60 d)
= 0.00124 * LW $^{0.75}$ * 60 (LW = live weight, kg)

Total manure N output for a year (365 days)
= Sum of manure N output during lactation and the dry period

An example of predicted manure N outputs (kg/365 days) for different production systems is given in Table 4 using average milk yields in 2001 obtained in Great Britain, Northern Ireland, Republic Ireland and France (Dairy Council, 2001). The results show that when assuming a constant live weight of 575 kg, it is predicted that cows in Northern Ireland excrete less manure N than those in Great Britain i.e., 7 to 9 kg/year or 8 to 10%. The values predicted for Great Britain are lower than standard values used by DEFRA (2002). France has the same value as Northern Ireland, while Republic of Ireland has the lowest value.

Dairy herd grazing

Table 4 Predicted manure N output for different countries using average milk yield in 2001

	Milk yield		Assumed live weight (kg)	Manure N output (kg)		
	Litre	kg		Lact.(305d)	Dry(60d)	Year
Great Britain	6800	7004	575	87-90	8.7	96-99
Northern Ireland	5900	6077	575	80-81	8.7	89-90
Republic of Ireland	4346	4476	575	66-68	8.7	75-76
France	5857	6033	575	80-81	8.7	88-90

A key objective of the present study was to determine the ‘typical’ manure N output of dairy cows in Northern Ireland. Given the strong correlation between milk yield plus live weight and N intake on a 305-day lactation basis, the N intake of the ‘typical’ cow can be predicted. Equation (2c) in Table 3 is considered the most appropriate and is therefore used for this calculation. The average milk yield in Northern Ireland from 2001 to 2003 was 6206 litres (Dairy Council, 2004), and assuming an average cow live weight of 570 kg, this equates to a ‘typical’ N intake of 114.2 kg for a 305-day lactation. The predicted manure N output over this ‘typical’ lactation is 82.5 kg/cow. This value, plus the manure N output of 8.7 kg for the dry period (60 days) gives a total manure N output of 91.2 kg/cow per year.

Losses of N from manure begin immediately following excretion. These losses occur as ammonia gas during housing, storage, land spreading and grazing. Therefore, the amount of N in manure at the time of land application is less than the total amount of N excreted. Inclusion of ammonia emission factors (Misselbrook *et al.*, 2000) for grazing, housing, manure storage and land spreading could lower the total N applied to land from dairy cows by up to 17 kg per head. Note that phosphorus excretion has not been considered in this study and this must be taken account of.

Dairy cows eating silage

STUDY 2:

PREDICTION OF MANURE N OUTPUT FOR BEEF CATTLE

General summary for Study 2

Data for 925 beef cattle were collated from 44 studies undertaken at ARINI from 1980 to 2003. This dataset has a wide range of live weight, total N intake and manure N output. Manure N output was very closely related to total N input (R^2 = 0.89), the same value as that derived from dairy cow data. Therefore, manure N output in beef cattle could be accurately predicted from total N intake. However, because there is little information available to enable prediction of total N intake over the entire growth period in beef cattle, this method cannot be used at present.

Data for 286 beef cattle with live weight records were taken as a subset from the above data to develop prediction equations. These equations indicate that live weight combined with dietary CP concentration can give an accurate prediction of manure N output for beef cattle.

The manure N output predicted from the present equations for an animal with a live weight of 500 kg and offered a diet containing a CP concentration of 140 g/kg DM is

Beef cattle eating silage

54 kg/year. This contrasts with the value of 58 kg/year used by DEFRA (2002) for a dairy heifer replacement, a suckler cow or a growing/fattening animal of 500 kg.

Details of Study 2

DATASETS

A total of 925 beef cattle data were collated from 44 studies undertaken at ARINI from 1980 to 2003. Forages offered were mainly grass silage, with the exception of 60 animals that were offered grass silage and whole crop wheat (n = 4) or grass silage and maize silage (n = 56) with the alternative forage accounting for less than 50% of total forage consumed. The forages were offered either alone as a sole diet (n = 94), or as mixed diets with concentrates or separately from concentrates (n = 831, dietary forage proportion ranging from 0.07 to 0.99). The statistical analysis indicated that total N intake was a better predictor of manure N output than live weight. However, no information is available to enable estimation of total N intake over the entire growth period of beef cattle. Therefore, it was not possible to use the entire data set for development of prediction equations.

The data set used for to develop the prediction equations was a subset of the data described above, where there were live weight records (n = 286). These 286 data were from 15 studies undertaken at ARINI between 1984 and 2003. The forages offered were mainly grass silage (n = 278) whilst four animals were offered grass silage plus whole crop wheat and four animals were given grass silage plus maize silage. In those experiments with alternative forages, the alternative forages accounted for less than 50% of the total forage consumed. The forages were offered either alone as a sole diet (n = 45), or as mixed diets with concentrates or separately from concentrates (n = 233, dietary forage proportion ranging from 0.20 to 0.84).

There was a wide range in live weight (153 to 580 kg), dietary CP concentration (108 to 217 g/kg DM) and forage proportion (0.2 to 1.0). Total N intake ranged from 73 to 316 g/d, manure N output from 43 to 227 g/d and manure N as a proportion of N intake from 0.57 to 1.05 g/g. The latter value related to a particular experiment in which no concentrates were offered. This large dataset is unique since there is no comparable information on beef cattle published elsewhere.

DEVELOPING PREDICTION EQUATIONS FOR DAILY MANURE N OUTPUT

The relationships between manure N output and total N intake and live weight are presented in Table 5 and Figures 3a and 3b. The accuracy of prediction of the relationship between manure N output and total N intake in this beef dataset (R^2 = 0.89, Equation (3a)) is very high and the same as that in the dairy cow data as reported previously in this report. Proportionately 0.774 of N intake is excreted in manure to leave 0.226 retained within the body of beef cattle (Equation (3b)). The proportion of excreted N in beef cattle (0.774) is higher than that in lactating dairy cows (0.721) as reported previously.

Table 5 Linear and multiple prediction equations for manure N output (g/d) # for beef cattle

	Equations	R^2	Eq. No
Manure N	$= 0.729\ (0.015)\ NI + 8\ (3)$	0.89	(3a)
	$= 0.774\ (0.004)\ NI$	0.89	(3b)
	$= 0.236\ (0.013)\ LW + 40\ (5)$	0.55	(4a)
	$= 1.345\ (0.073)\ LW^{0.75} + 15\ (6)$	0.55	(4b)
	$= [0.217\ (0.101) + 8.216\ (0.608)\ CPc]\ LW^{0.75} + 4\ (5)$	0.72	(4c)

CPc = CP concentration in diets (kg/kg DM); LW = live weight (kg); NI = total N intake (g/d)

Suckler cow and calf

Beef cattle at grass

There was also a significant ($P < 0.001$) relationship between live weight and manure N output ($R^2 = 0.55$, Equation (4a) and (4b)). Although this R^2 value is much lower than that for total N intake (0.55 vs. 0.89), it is much higher than for the same relationship for dairy cows (0.22) reported previously in this project.

The statistical analysis indicates that total N intake is a better predictor of manure N output than live weight in beef cattle. This finding is the same as that for dairy cows as reported previously. However, it is difficult to accurately estimate total N intake from weaning to slaughter for beef cattle. Live weight is however widely available in practice and has a relatively good relationship with manure N output. Live weight was therefore selected as a primary predictor for manure N output. Adding forage proportion of the diet to this relationship had no significant effect, while using dietary CP concentration as a secondary variable to live weight for prediction of manure N output significantly increased the R^2 value to 0.72 from 0.55 (Equation (4c) vs. (4a) and (4b)). The accuracy of these prediction equations was validated using the ARINI data. Equation (4c) is therefore recommended.

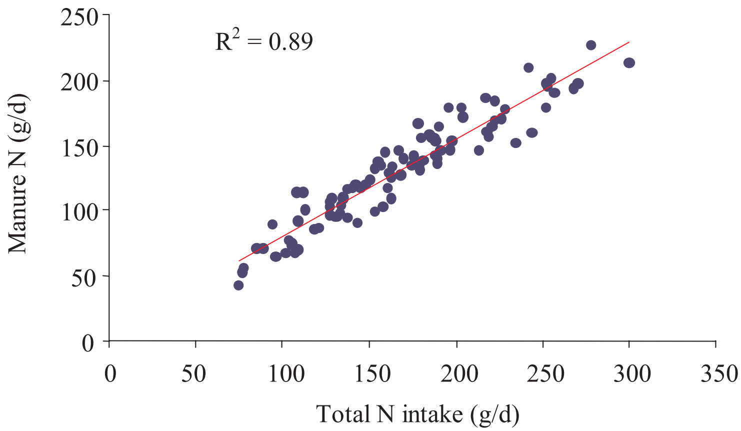

Figure 3a Relationship between manure N excretion (g/d) and N intake (g/d) in beef cattle. (Manure N = 0.774 x N intake) (Equation 3(b)).

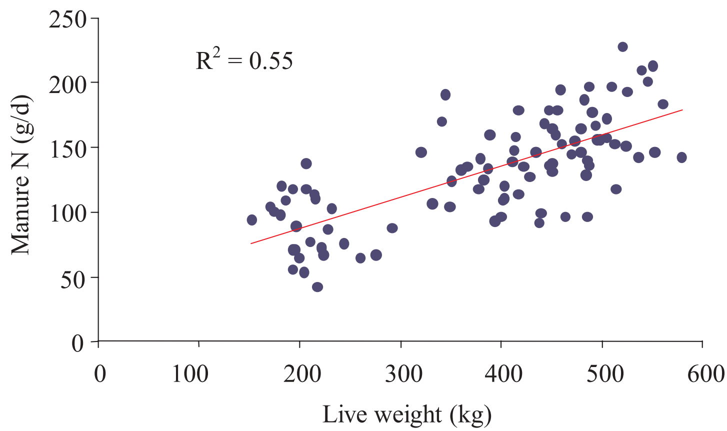

Figure 3b Relationship between manure N excretion (g/d) and live weight (kg) in beef cattle. (Manure N = 0.236 x LW + 40) (Equation 4(a)).

IMPLICATIONS OF THE PRESENT MODELS

The manure N outputs proposed by DEFRA (2002) and those calculated from Equation (4c) are presented in Table 6. The ARINI prediction equation produces a range of manure N outputs depending on dietary CP concentration. Using a dietary CP concentration of 140 g/kg DM results in a predicted manure N output of 4 kg/year less than that used by DEFRA for the first three groups of cattle.

Table 6 Manure N output proposed by DEFRA and ARINI equivalents predicted using live weight with a range of dietary CP concentrations (Eq. (4c)) #

	DEFRA Proposal	ARINI Eq. (4c) Dietary CP (g/kg DM)		
		130	**140**	150
	Manure N output (kg/year)			
Dairy heifer replacement over 24 months #	58	51	**54**	57
Suckler cow	58	51	**54**	57
Cattle grower/fattener over 24 months #	58	51	**54**	57
Cattle grower/fattener 12-24 months ##	47	43	**46**	49

Live weight = 500 kg
Live weight = 400 kg

STUDY 3:

NUTRITIONAL STRATEGIES TO IMPROVE THE EFFICIENCY OF UTILISATION OF DIETARY NITROGEN IN MILK PRODUCTION

General summary for Study 3

A dataset was collated from six detailed dairy cow studies at ARINI with 47 treatments on protein nutrition. Diets ranged in protein content from 125 to 250 g/kg DM. Dietary concentration of protein had highly significant positive linear relationships ($P<0.001$) with forage DM intake (R^2 = 0.80) and milk yield (R^2 = 0.82) but had no effect on the butterfat or protein content of the milk. Dietary concentration of protein had significant negative linear relationships with efficiency of utilisation of dietary protein, in terms of conversion of dietary protein to milk protein (R^2 = 0.82). Reducing the concentration of dietary protein from 210 to 160 g/kg DM improved the capture of dietary protein as milk protein by 27% and reduced the excretion of N by 26 kg/cow across a typical lactation. However, this was accompanied by a reduction in daily milk yield of 1.6 kg/d for around the first half of the lactation with a smaller reduction thereafter equivalent to reduction in total lactation yield of approximately 350 litres. This potential reduction in excreted (manure) nitrogen is important within the context of the proposed Nitrate Vulnerable Zone legislation.

Details of Study 3

A range of factors can affect the efficiency of N use in milk production systems e.g. stage of lactation, lactation yield, fertility, replacement rate, grazing vs. use of conserved forage and level and form of N application. Study 3 focused on nutritional strategies which offer potential to improve the efficiency of N use in dairy cows in order to reduce N losses.

DATASET

A dataset was assembled from six nutrition studies with 47 treatments carried out at ARINI over the past 25 years. All of the experiments involved winter feeding of dairy cows in early or mid lactation with grass silage as the main forage. In commercial dairy cow feeding, the protein content of both the forage and the concentrate supplement can vary widely. Therefore, a major focus of the present study was to explore the production responses of dairy cows to different concentrations of crude protein (CP) in the total ration and the associated effects on the efficiency of protein utilisation.

EFFECT OF CRUDE PROTEIN CONCENTRATION ON FOOD INTAKE, MILK YIELD AND MILK COMPOSITION

High food intakes are dependent on good rumen function which in turn depends on an adequate supply of rumen available protein. High levels of milk production require an adequate supply of both microbial protein and bypass protein i.e. metabolisable protein. Five equations were developed to determine the effects of dietary CP concentration on feed intake, milk yield and efficiency of CP utilisation (Table 7, Equations (5a) to (5f))

There was a good relationship between concentration of dietary crude protein and forage intake (Equation (5a)) with an increase in diet crude protein content of 50 g/kg DM producing an increase in forage intake of 0.79 kg DM/d, while total DM intake increased by 0.59 kg/d (Equation (5b)).

Table 7 The relationships between dietary CP concentration (CPc, g/kg DM) and feed intake, milk yield and efficiency of N utilisation

Equations	R^2	Eq. No
Forage DM intake (kg/d) = 6.75 + 0.0159 CPc	0.80	(5a)
Total DM intake (kg/d) = 14.72 + 0.0139 CPc	0.59	(5b)
Milk yield (kg/d) = 18.5 + 0.0321 CPc	0.86	(5c)
Fat + protein yield (kg/d) = 1.348 + 0.00222 CPc	0.82	(5d)
Milk CP output/CP intake (g/kg) = 521 - 1.32 CPc	0.92	(5e)
Excreted N/milk yield (g/kg) = - 2.2 + 0.0864 CPc	0.92	(5f)

Similarly, both daily milk yield and yield of fat plus protein showed strong relationships with dietary concentration of crude protein (Equations (5c) and (5d) respectively). An increase of 50 g/kg DM in dietary CP concentration increased milk yield by 1.6 kg/d averaged across the relatively wide range of protein concentrations present in the dataset (125 to 250 g CP/kg DM).

Across the range of dietary concentrations of protein there was no significant relationship with either protein or butterfat content of milk.

EFFICIENCY OF PROTEIN UTILISATION

While forage intake and milk yield have shown good relationships with dietary protein concentration, the efficiency of use of dietary protein, in terms of capture as milk protein, is important. The ratio of milk protein output/crude protein intake (g/kg) provides a simple measure of overall efficiency of capture of dietary protein in milk output. The mean ratio across all of the studies was 275 g/kg. This ratio declined linearly as crude protein content increased (Equation (5e)) from 310 at 160 g/kg DM protein in the diet to 244 at 210 g/kg DM protein. This indicates a lower efficiency of N recovery as CP concentration in the diet increased.

Another measure of efficiency of protein utilisation is the ratio of excreted nitrogen (N) to milk yield. Ratios of 11.6 and 15.9 g excreted N/kg milk were obtained at dietary protein concentrations of 160 and 210 g/kg DM respectively (Figure 4 and equation 5(f)). In other words, excreted N increased by 4.3 g/kg milk when dietary protein concentration was increased by 50 g/kg.

It is evident, therefore, that whilst there are positive milk production responses to high protein diets, the efficiency of capture of dietary protein in milk declines in direct response to increasing protein content of the diet. Lowering overall diet crude protein from 210 to 160 g/kg DM improved the proportion of dietary protein captured in milk by 27% but this must be set against a concomitant reduction in food intake of 0.69 kg DM/day and in milk yield of 1.6 kg/d.

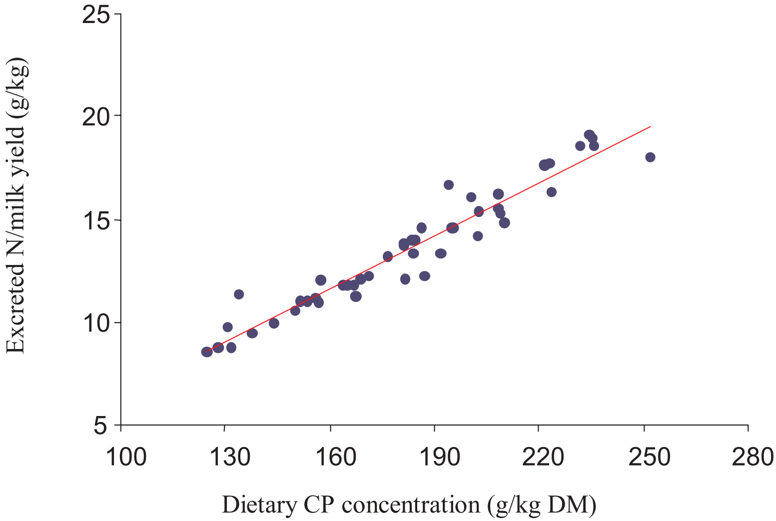

Figure 4 Relationship between dietary CP concentration and excreted N/milk yield

It is calculated that over a 6000 kg (305 day) lactation, a reduction of 50 g/kg DM in dietary protein would reduce excreted nitrogen by 26 kg/cow/lactation. However, this would also be associated with a reduction in milk yield of approximately 350 kg/lactation (i.e. 6% reduction).

THE EFFECTS OF OTHER FACTORS ON PROTEIN EFFICIENCY

Protected protein

Two studies were carried out with rumen protected soya bean meal. There was no significant effect on either milk production or protein efficiency from feeding higher levels of protected protein. i.e. there was no effect on the proportion of dietary protein captured as milk protein or excreted N per kg of milk produced. These results have to be considered in the context that the forage base of the diet in both studies was good quality grass silage. There is some evidence in the literature of responses to protected protein when fed with lower protein forages e.g. maize silage.

Level of concentrate feeding

Data from two recent studies were examined to investigate the effect of level of concentrate feeding on protein efficiency (Table 8). It is evident that protein efficiency (i.e. milk protein output as a proportion of diet CP intake) was lower with both of the high concentrate diets. However, when adjustment is made to the protein efficiency indicators for the higher protein content of the high concentrate diets, the effect of level of concentrate depends on the magnitude of the milk production response to the higher level of concentrates. In Experiment 2, 0.98 kg milk/kg additional concentrate DM intake was fully maintained at the adjusted protein efficiency ratio. In contrast, the lower response in Experiment 1, 0.41 kg milk/kg additional concentrate DM intake, was associated with reduced protein efficiency in terms of both capture of dietary protein in milk or excreted N per kg of milk produced.

Table 8 The effects of level of concentrate feeding on protein efficiency with dairy cows

	Concentrate DM intake (kg/d) DM intake	Total DM intake (kg/d)	Dietary CP (g/kg DM)	Milk yield (kg/d)	MilkCP CP intake (g/kg)	Excreted N/ milk yield (g/kg)
Experiment 1						
Low concentrate	7.8	17	196	27.9	263	14.1
High concentrate	12.2	20	208	29.7	231	17.3
High concentrate #	-	-	196	-	246	16.3
Experiment 2 ##						
Low concentrate	3.5	13.7	149	18.4	290	12.6
High concentrate	9	17.1	173	23.8	282	14.2
High concentrate#	-	-	149	-	314	12.2

High concentrate adjusted dietary protein concentration
Values for 305 day lactation

Genotype

The effect of genotype on milk production with Holstein Friesian type animals with high, medium and low genetic potential for milk production has been studied at ARINI. These data relate to the first 150 days of lactation with a common concentrate ratio of 0.64 of total DM intake. From this study, the high milk yields that were associated with higher genetic potential on equal quality of diet, improved the utilisation of dietary protein in terms of both protein capture in milk and reduced the output of excreted N per kg of milk from the production system.

These findings suggest that high genetic potential for milk yield can have strong positive direct effects on protein efficiency. However, it is recognised that some of the potential improvement in protein efficiency associated with high genetic potential may be lost if higher genetic potential for milk yield is associated with higher rates of herd replacement.

Stage of lactation

The efficiency of use of protein in the lactating cow depends on the relationship between level of milk production and level of protein in the diet. Level of production is not constant during lactation and consequently protein efficiency changes during lactation. Figure 5 shows that protein efficiency can be very high in early lactation but then declines due to the reduced level of milk output. In order to maintain high levels of protein use efficiency, high levels of production of the individual animal need to be maintained and diet CP content should be reduced in mid and late lactation in order to maintain a high ratio of protein capture in milk and low outputs of excreted N. Equally, protein efficiency can be improved with lower genetic merit cows by reducing the protein content of the concentrate.

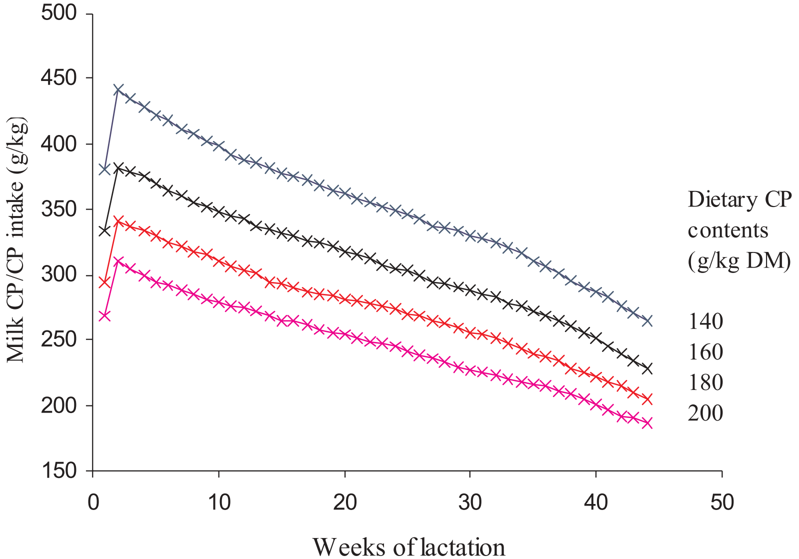

Figure 5 The effect of crude protein (CP) content of the diet and stage of lactation on efficiency of nitrogen (CP) recovery in milk (adapted from Topp and Hameleers, 1998 and 1999)

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ACKNOWLEDGEMENT

The research team gratefully acknowledge the assistance of C. Ferris, S. Gilkinson, L. Jarvis, K. Mathers, M. Porter, R. Steen and A. Hameleers in the collation of the data for this project.

AGRISEARCH BOOKLETS

1 SHEEP
The Effects of Genetics of Lowland Cross-Bred Ewes and Terminal Sires on Lamb Output and Carcass Quality
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2 DAIRY
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