A Nuffield Farming Scholarships Trust Report

Award sponsored by

Royal Welsh Agricultural Society and McDonald's Restaurants

Sustainable protein feeding

for the

UK Dairy Industry

Iwan Vaughan

July 2018

NUFFIELD UK

NUFFIELD FARMING SCHOLARSHIPS TRUST (UK)

Awarding life changing Scholarships that unlock individual potential and broaden horizons through study and travel overseas, with a view to developing farming and agricultural industries.

"Leading positive change in agriculture"

"Nuffield Farming" study awards give a unique opportunity to stand back from your day-to-day occupation and to research a subject of interest to you. Academic qualifications are not essential, but you will need to persuade the Selection Committee that you have the qualities to make the best use of an opportunity that is given to only a few – approximately 20 each year.

Scholarships are open to those who work in farming, food, horticulture, rural and associated industries or are in a position to influence these industries. You must be a resident in the UK. Applicants must be aged between 22 and 45 years (the upper age limit is 45 on 31st July in the year of application). There is no requirement for academic qualifications, but applicants will already be well established in their career and demonstrate a passion for the industry they work in and be three years post tertiary education. Scholarships are not awarded to anyone in full-time education or to further research projects.

Full details of the Nuffield Farming Scholarships can be seen on the Trust's website: www.nuffieldscholar.org. Application forms can be downloaded but only online submission is accepted.

Closing date for completed applications is the 31st July each year.

ISBN: 978-1-912059-21-8

Published by The Nuffield Farming Scholarships Trust
Southill Farm, Staple Fitzpaine, Taunton, TA3 5SH
Tel: 01460 234012
Email: director@nuffieldscholar.org
www.nuffieldscholar.org

A Nuffield (UK) Farming Scholarships Trust Report

"Leading positive change in agriculture. Inspiring passion and potential in people."

Date of report: July 2018

Title	Sustainable protein feeding for the UK dairy industry
Scholar	Iwan Vaughan
Sponsor	Royal Welsh Agricultural Society and McDonald's Restaurants
Objectives of Study Tour	• To reduce ammonia emissions from dairy production through feeding less N. • Increasing N utilisation within the rumen. • To reduce the need for purchased protein inputs. • To increase cow health, fertility and production.
Countries Visited	USA, Canada, Netherlands, Ireland, Dubai Australia, New Zealand and Ireland
Messages	• Ammonia emissions can be reduced through low crude protein diets. • Industry needs to get away from formulated to crude protein. • Need a more accurate feed analysis for UK forages, and model the diet correctly. • Increase feed efficiency for environmental sustainability. • Realise the potential DM yield of your farm before purchasing more feed.

EXECUTIVE SUMMARY

As a dairy farmer working within the feed industry I am constantly frustrated by looking at unbalanced formulated diets which can be damaging to the health of the cow and the farmer's pocket, as well as the environment. Crude Protein (CP) is the industry standard figure to express the level of protein within a diet. CP is only a measure of the nitrogen (N) multiplied by 6.25.

Research shows that only approximately 30% of the nitrogen (protein) that we feed to ruminants is converted to animal protein such as milk or meat (*Dewhirst, 1996; Firkins, 1996*). The rest can be lost either in the urine, the faeces or lost as urea within the milk. N excreted in the faeces and urine has the potential to be lost as ammonia to the atmosphere.

The key objectives of my report were to research and evaluate how to formulate low protein diets and maintain or increase production through increasing rumen N efficiency and capturing more of the N we feed by converting it into a saleable protein product such as milk or meat. This reduces the need to purchase expensive protein inputs which can be one of the highest costs on a dairy farm. Having a balanced diet would increase cow health and fertility as well as increasing environmental sustainability by reducing the risk of ammonia emissions.

During this project I travelled to the USA, Canada, the Netherlands, Dubai, Australia, New Zealand and Ireland, visiting research intuitions, meeting dairy nutritionists and consultants, along with visiting dairies from large housed herds to fully grass-based herds.

This report highlights that diets in the UK can be formulated with lower protein. However, the report also emphasises the need for more accurate feed analysis of our forages to help understand our fibre in order to increase fermentable carbohydrates within the diet and assist in achieving higher microbial protein yield. This can help increase rumen N efficiency and reduce secreted N. As an industry we need to get away from formulating diets to crude protein and feed for the level of amino acids that the animal requires. This would make us more efficient in utilising the protein we feed.

To further increase environmental sustainability of dairy farming we need to look at increasing feed efficiency to get more out of what we put in. We also need to realise the potential of our own farms to produce feed and increase DM yields before buying in feed in the form of forage or concentrates.

As a proud UK dairy producer, I am determined to improve both public perception and environmental sustainability, whilst increasing the profitability of UK dairy farming. I hope this report will assist in addressing some of these issues for both farm and industry.

Contents

Glossary of Acronyms

AA- Amino Acid

AMTS- Ag Model and Training System

BMR- Brown Mid-rib

CNCPS- Cornell Net Carbohydrate and Protein System

CP- Crude Protein

DM- Dry Matter

DMI- Dry Matter Intake

FYM- Farm Yard Manure

GM- Genetically Modified

MP- Metabolisable Protein

MUN- Milk Urea Nitrogen

N- Nitrogen

NDF- Neutral Detergent Fibre

uNDF- Undigestible Neutral Detergent Fibre

NPN- Non Protein Nitrogen

NVZ- Nitrogen Vulnerable Zone

P- Phosphorus

RDP- Rumen Degradable Protein

S- Sulphur

SARA- Sub Acute Rumen Acidosis

TMR- Total Mixed Ration

VFA- Volatile Fatty Acid

DISCLAIMER

The opinions expressed in this report are my own and not necessarily those of the Nuffield Farming Scholarships Trust, or of my sponsor, or of any other sponsoring body.

CONTACT DETAILS

Iwan Vaughan

Maesmochnant Uchaf,
Llanrhaeadr ym Mochnant
Oswestry,
Shropshire,
SY10 0AF

Tel: 01691 780209   Mob: 07990 578548

iwan.vaughan@wynnstay.co.uk

iwan.vaughan12@gmail.com

Nuffield Farming Scholars are available to speak to NFU Branches, Agricultural Discussion Groups and similar organisations

Published by The Nuffield Farming Scholarships Trust
Southill Farmhouse, Staple Fitzpaine, Taunton TA3 5SH
Tel : 01460 234012
email : director@nuffieldscholar.org
www.nuffieldscholar.org

1.0. Introduction

From an early age I knew my future would be within the agricultural industry. Growing up on the family farm, it soon became apparent my passion for livestock and food production would stay with me and carve my future career.

I grew up on the family farm at Llanrhaeadr ym Mochnant, in rural north Montgomeryshire. The family runs a 200ha mixed livestock farming enterprise, which is spread over multiple units, with a mixture of low valley ground along with steep upland. The farming operation includes a dairy herd of 140 autumn calving cows. All the youngstock are reared on farm either as replacement dairy heifers or finished as heifers or bulls. The farm also runs just over 1000 cross bred breeding ewes, with all lambs sold to slaughter.


Figure 1: The author, Iwan Vaughan

Running a mixed livestock farm, my target has always been to maximise output from what we can grow on the farm and share resources within each enterprise, hoping to achieve a more resilient and profitable business. Being involved with dairy, beef and sheep, I have interests across all ruminant sectors; however, dairy has always been my focus.

Although still involved with the running of the farm day to day, being one of three sons I always knew my full-time role wouldn't be at home. However, I wanted to stay involved with the industry.

My interest and passion for ruminant nutrition came as the first mixer wagon arrived on farm in 2005. It was then I first started to consider how to make the most of the home grown forage we grew on the farm and how to increase output from the milking herd through the way we fed them.

From 2007-2010 I studied Agriculture with Animal Science at Aberystwyth University and, upon graduating, started working for Wynnstay Group PLC. Starting as a sales representative I was given the opportunity to pursue further training and completed a Diploma in Ruminant Nutrition at Harper Adams University.

In 2012 my role changed to becoming a Dairy Technical Specialist. The role involved working closely with the Wynnstay sales team in supporting and advising farmers across the trading area on dairy management and nutrition. My main objective in the role was to have a positive effect on their business going forward.

From July 2018, I took up the role of Head of Dairy Technical Services at Wynnstay, managing the Dairy Technical Team. Although a relatively new post, I am thoroughly looking forward to the challenge.

2.0. Background to my study

As a dairy farmer working within the feed industry I am constantly frustrated by looking at unbalanced formulated diets which can be damaging to the health of the cow and the farmer's pocket, as well as the environment.

Protein is seen as a valuable component in the makeup of any diet. Crude Protein (CP) is the industry standard figure to express the level of protein within a diet. This, as the name suggests, is very 'crude' in the way it is expressed, and is only a measure of the nitrogen (N) rather than a measure of quality or true protein within the diet.

Research shows that only approximately 30% of the nitrogen (protein) that we feed to ruminants is converted to animal protein such as milk or meat (*Dewhirst, 1996; Firkins, 1996*). The rest can be lost either in the urine, the faeces or lost as urea within the milk. N excreted in the faeces and urine has the potential to be lost as ammonia to the atmosphere, which poses huge environmental challenges and reflects the need to be proactive in reducing nitrogen secretion and capturing more nitrogen within the rumen.

> *The aim of this report … is to question if there is a way we can reduce protein intake but still maintain or boost protein output.*

Protein has historically been overfed in the UK with the CP in diets being far higher than required. This is mainly due to the use of poorer quality raw materials of lower protein quality. Proteins have been overfed as an insurance for poorer management and fear of lack of performance. Proteins in the past have been relatively cheap; however, with increasing farm input costs, feed efficiency must be paramount to achieving their business goals.

At the cow's level, overfeeding protein can have a negative effect on energy balance and condition, which can affect fertility and the cows' health.

The aim of this report therefore is to question if there is a way we can reduce protein intake but still maintain or boost protein output in the form of milk or meat.

3.0. My Study Tour - where I went and why

I would like to set out where and why I travelled to various destinations during my 8 weeks of personal travel.

Date	Where	Why
September 2017	**New York State, USA**	To visit Cornell University to speak to key researchers who developed the CNCPS (Cornell Net Carbohydrate and Protein System) which is their nutrition model. This was also an opportunity to visit top quality dairies within the region.
September 2017	**Wisconsin, USA**	Wisconsin is seen as the main dairy state in the US. I had to take this opportunity to visit dairies and discuss with nutritionists and consultants who were out in the field, as well as meet researchers at Wisconsin University.
September 2017	**Colorado, USA**	To gain information on feed efficiency and breeding within the beef industry to help understand how this could be applied in dairy.
September 2017	**Ontario, Canada**	The opportunity to speak to key researchers at Guelph University as well as speaking to model developers and nutritionists within the region.
October 2017	**Netherlands**	To attend Wagningen Dairy Conference. The Netherlands have some of the best grass silages in the world. On this trip I was looking at their N and P restrictions.
November 2017	**Dubai**	To visit dairies which import nearly all of their feed.
November 2017	**Victoria, Australia**	Understanding milking in challenging climates, and grazing/feeding multiple crops to address the situation.
November 2017	**New Zealand**	Milk from grass and understanding its potential. Environmental issues on grazing systems and how best to overcome them.
June 2018	**Ireland**	Understanding grass digestibility and management and how best to supplement.

When setting out to plan my personal travel I knew I wanted to speak to farmers and dairy operators on the ground, working hands-on day-to-day to help understand their systems and management strategies, and what were their leading objectives on the farm. I also wanted to arrange visits and days on farm with nutritionists and consultants to see what their approaches were, and what their main challenges and successes were.

Nutrition is basically simple mathematics, and diet models are built on equations. I therefore wanted to meet some of these modellers and also visit universities and research institutions to get a greater understanding of which models may work better on UK diets.

4.0. Protein - what's the big deal

Ruminants are fascinating creatures. What sets them apart from monogastric organisms with one simple stomach, is that they possess a huge fermentation chamber known as the rumen, which is full of a microbial population made up of bacteria, protozoa and fungi. This microbial population is able to break down poor quality forage and raw materials into essential nutrients that can be used for body function and performance. The bugs are able to break energy sources down into volatile fatty acids (VFAs) and the rumen bugs are able to use the energy and protein to multiply and to create microbial protein.

The building blocks of protein are Amino Acids (AA) and there are 20 different AAs; these are essential for body function as well as performance in terms of growth or yield. There are 10 essential amino acids, which are: phenylalanine, valine, threonine, tryptophane, isoleucine, methionine, histidine, arginine, leucine, and lysine. Lysine and methionine are the most recognised as having limitations in ruminant diets and may need supplementation, otherwise performance will be compromised. More research is required on the other essential AAs.

It is assumed that AAs contain 16% N. The percentage CP is calculated by multiplying the percentage of N in the feed by the factor 6.25 (100/16). Each AA has a different N content and 16% is only an average. Table 1 below shows the difference in N percentage of various AAs. It demonstrates that CP is an inaccurate form to measure AA supply to the animal.

Table 1: Percentage N in Essential AA

Amino Acid	%N	Amino Acid	%N
Methionine	9.388	Histidine	13.718
Lysine	19.164	Threonine	11.759
Arginine	32.164	Tryptophane	27.085
Valine	11.958	Leucine	10.68
Isoleucine	10.679		

(*source: Van Amburgh*)

The cow requires AA, which is able to be absorbed from Metabolisable Protein (MP), which is the protein available for absorption by the animal in the small intestine. This is a combination of microbial protein, and rumen bypass protein.

Rumen degradable protein (RDP), can be supplied as NPN (non-protein nitrogen) or true protein (Amino N as shown below in figure 2), and is broken down to ammonia in the rumen. This is used to create microbial protein as the rumen bugs multiply. The rumen bugs also need sufficient fermentable carbohydrates (starch and sugar) to feed the bugs' energy. If there is too much ammonia and insufficient energy, ammonia will build up and passes through to the bloodstream. Ammonia is toxic to ruminants so is converted to urea in the liver. There is an energy and metabolic cost to doing this which can affect performance.

A proportion of protein is also bypass which passes through the rumen to the abomasum and further to the small intestine and is available along with microbial protein as MP. You can supplement bypass protein and protected AA to get the essential AA required. Both the microbial protein (60-65% supplied) and bypass (30-35% supplied) make up the MP requirement for the animal.

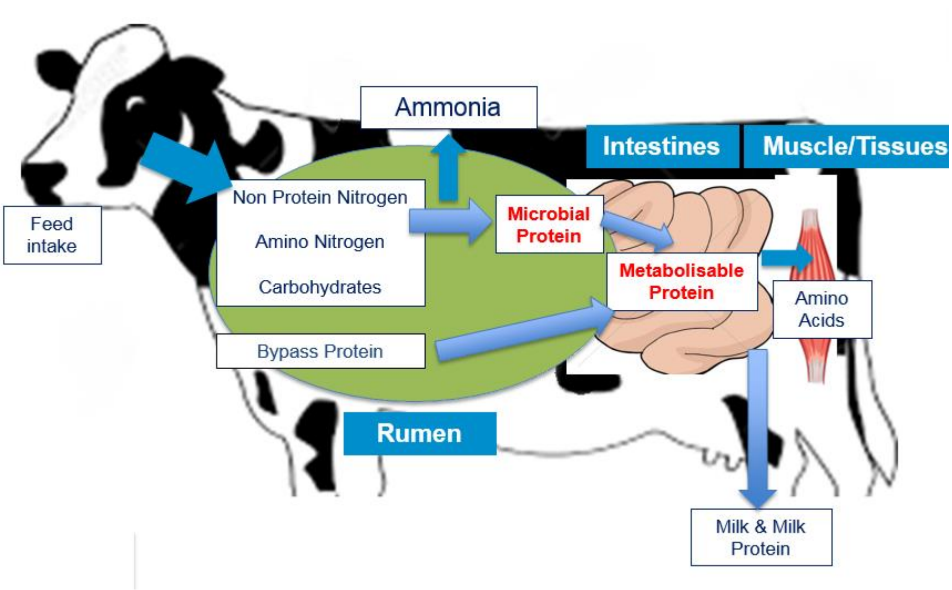

Figure 2 : Metabolisable Protein Production. Source: Author

Of the protein (N) the average cow consumes, only 25-30% is converted into a saleable protein product e.g. milk protein. Professor Michael Van Amburgh at Cornell University said that the most efficient cow they have had on trial was 45% efficient. This was on a 13% CP diet. Although there is no chance of becoming 100% efficient, there are opportunities to close the gap between current performance and the potential of the cow.

Professor Jim Gibbs from Lincoln University, New Zealand, explained to me his definition of rumen N efficiency:

> *'The amount of N utilised is constant, regardless of the N we feed. Changes to the diet won't increase how much N the cow uses, but a reduction in N intake will increase utilisation'.*

This shows that the key message to increase rumen N efficiency in UK diets is to reduce the intake of N. However, I am intrigued to see if we can increase microbial protein synthesis and capture more N within the rumen.

5.0. Environmental concerns of overfeeding excessive N

Efficiency of protein use within our diets is key to reducing the N within our slurry and farm waste. Of the N lost through excretion, the N contained in urine is most volatile and can be easily converted from ammonia to nitrous oxide. This is a greenhouse gas and 298 times more potent than carbon dioxide (*EPA, 2017*). Nitrate run-off and leaching are a huge environmental concern, both to our waterways and also to water quality.

Dairy production globally needs to reinvent itself and improve its public perception. During my travels I have already seen sanctions being put in place for dairy farmers in the Netherlands and New Zealand.

New Zealand has gone through challenging times to hold on to their green image in dairy production. The increase in grass-based dairies throughout New Zealand has meant that severe sanctions have been put in place to safeguard water quality.

The majority of lifetime losses (of N) in cattle are accounted for by milk production and the inefficiency of converting feed N into milk N.

In the Netherlands restrictions are in place which limits N and P (Phosphorus): cow numbers are restricted per ha, to reduce the output of N and P being spread back on the land through manure. With such restrictions in place to reduce N and P output, farmers in the Netherlands have to be proactive in their approaches to feeding, manure and waste management.

This starts with rethinking the way they bring N onto the farm, not only in fertiliser form but also lowering the amount of N by reducing bought-in feed protein. Grass, when harvested at the correct stages, can be very high in CP. To minimise the amount of protein Dutch farmers purchase for their farms, they ensure they harvest as much protein as possible on their own farms; by cutting the grass young and so ensuring maximum amounts of N within the crop that can be fed back to the livestock. Producing higher yields of milk protein per cow also increases efficiency and output per ha.

I discussed with Andreas Foskolos and Jon Moorby at Aberystwyth University a model they had developed to monitor Cattle N Efficiency (CNE). This calculated total lifetime N efficiency and losses. The majority of lifetime losses in cattle are accounted for by milk production and the inefficiency of converting feed N into milk N. The model shows that, on average in the UK, 72% of the N intake is excreted *(Foskolos and Moorby, 2018).*

Although milk production is the major factor, there were 5 other areas that significantly affect N lifetime efficiency:

- Heifer growth - time and N required before start of 1st lactation.
- Heifer removal - heifers sold or died before the start of 1st lactation.
- Pregnancy - the N required to maintain a pregnancy.
- Cow removal - culls sold or died, how much N harvested as meat.
- Disease and fertility - how disease and poor fertility can affect milk yield.

6.0. Sustainable protein

The definition of sustainability is '*the ability to be maintained at a certain rate or level*', and the definition of environmental sustainability is '*avoidance of the depletion of natural resources in order to maintain an ecological balance*' (Google Dictionary, 2018).

Ruminants are seen as being very inefficient in converting DM to an end product such as milk or red meat. It is important to increase the efficiency of ruminant industries as, in the future, we may come under threat of more efficient man-made protein such as laboratory-produced synthetic meat.

> **With this in mind we must think which protein feed sources are sustainable for feeding ruminants, especially dairy, in the future.**

Soybean meal is a proportion of the purchased protein we bring onto UK dairy farms. This is mainly imported from North and South America. During my time in Mato Grosso, Brazil, I saw the full scale of soybean production with vast areas of land laid down to soybeans. My personal perception of Brazil - before heading out there - was the unsustainable activity of growing crops for export after deforestation. Although deforestation is illegal, it is still evident in the Amazon region in the north of the country. However, the majority of produce coming out of Brazil would be coming from the central and southern states - where scrub had been cleared - rather than from rain forest.

Figure 3: Me, along with Ed Payne and Hugh Shedden in a 60,000t soybean store on a 240,000ha unit in Mato Grosso.

Soya will still be grown across the world and sold as a commodity and it will always be available, but we need to start thinking of restricting imported soya within our diets and finding protein sources with good AA profiles closer to home. This may include UK-grown soybean in the future. If we can grow the required protein in the UK there is no point feeding a product with a higher carbon footprint that has been shipped from the other side of the world.

Other pulses within the UK have a similar AA profile to soya. These include field beans and peas. Beans work really well within diets: adding protein and starch, driving microbial protein synthesis and supplying a good AA profile as they are high in lysine. Peas on the other hand are both higher in lysine and methionine than either soya or beans. Both crops work great in an arable rotation, and as both are legumes they fix their own N.

Legumes including red clover are great options for home grown protein. Dr Jon Moorby, from Aberystwyth University, explained how red clover can have a higher true protein content compared to forage such as grass, as enzymes - including polyphenol oxidase - bind to the protein and stop it breaking down after harvest. This means more of the protein in red clover is true protein and available within the rumen.

I came to the conclusion that insect protein may be the future; however, at the current time, there are greater opportunities for insect protein within marine and poultry feed.

When I started my Nuffield Farming journey I was interested in developing insect protein for ruminants, thus producing a high quality protein source from waste products. This would be very efficient and tick all the boxes in terms of protein sustainability. After discussing the subject with Dr Aidan Leek NSch and reading his Nuffield Farming report I came to the conclusion that insect protein may be the future; however, at the current time, there are greater opportunities for insect protein within marine and poultry feed.

Insect protein is only currently registered as a feed in the EU for marine, and would currently be too expensive to be considered in ruminant diets. This may change in the future and become a viable option.

But to have an impact on the dairy industry in the short term I focused on increasing rumen N efficiency with feed materials which are available.

7.0. We need to understand fibre

7.1. CNCPS

By visiting Cornell University, I became more familiar with the CNCPS (Cornell Net Carbohydrate and Protein System) dairy nutrition model. Many nutrition models on the market are static models which use standardised relationships between variables. Figures such as DMI and rumen outflow are standardised to try and determine the nutrient contribution from the rumen. CNCPS version 7 (V7), which will be released shortly, is a mechanistic model which calculates DMI and rumen outflow, along with a range of parameters, by calculating the biology of what the inputs are. This gives us great accuracy when formulating.

Comparing this model to other current models used within the UK, it is clear that the CNCPS model can more accurately predict performance on the farm. Forage feed analysis can be the most important input to most diets as it is generally the largest fraction of the diet. With more accurate analysis of NDF digestibility we can predict DMI and performance.

Figure 4: Me at Cornell University

The key message I took from Prof. Michael Van Amburgh during my time in Cornell University was that we needed to understand NDF (Neutral Detergent Fibre) before being able to feed cows. Through understanding NDF we are able to manage the fermentable carbohydrates within the rumen and increase microbial protein synthesis.

Dr Tom Tylutki, President and CEO of AMTS (Ag Model and Training Systems), one of the software platforms which runs the CNCPS model, explained that SARA (Sub-acute Ruminal Acidosis) is an issue related to passage rate. He explained that we need to slow the rumen down and keep it full of NDF. We can increase starch within the diet, but we need to provide the rumen with enough NDF first.

7.2. Fibre pools

Neutral Detergent Fibre (NDF) is a fraction commonly seen on a feed analysis sheet. It indicates the total fibre content of the plant and includes the hemi-cellulose, cellulose and lignin. However, on most current UK feed analysis sheets there is no breakdown of the digestibility and how fast the NDF degrades within the rumen.

NDF and its digestibility plays a huge role in determining DMI (Dry Matter Intake). A faster disappearance of the NDF fraction within the rumen, because of the increased rate of digestion or passage, will reduce physical fill in the rumen over time and promote higher feed intake (*Dineen and Van Amburgh).* This shows that digestibility of NDF can influence performance of growth and milk yield even if NDF levels are similar in diets.

NDF can be broken down into 3 further 'pools'. NDF which hasn't been degraded within 240 hours will be classified as uNDF (Undegradable Neutral Detergent fibre). This has an important role in contributing to the rumen to provide physical fill but cannot be broken down and support microbial protein synthesis and VFA production. Higher uNDF is closely linked to stage of maturity as it has gone through a period of stress and growing where crosslinking and lignification has occurred.

The remainder of the NDF fraction is potentially digestible and is available for the rumen microbes. This can be broken down into two further sections: fast pool and slow pool. Certain time points of degradability, depending on the feed material, will determine the pool within each forage. Having access to this data will enable nutritionists to fully understand intakes and degradability and formulate accordingly to achieve far higher accuracy in results.

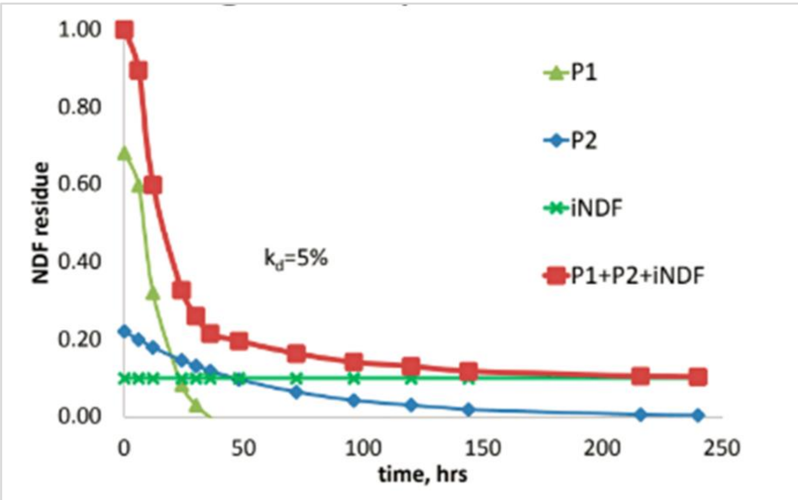

Figure 5: Graph demonstrating the 3 Pools of NDF. ***(source: Van Amburgh Slides)***

Key:
P1- Fast pool
P2- Slow pool
iNDF = uNDF

To be able to achieve a healthy rumen and microbial population the rumen always needs a certain level of NDF within the rumen. This level changes depending on the stage of lactation, but a rule of thumb would be 1.2% of bodyweight should be NDF.

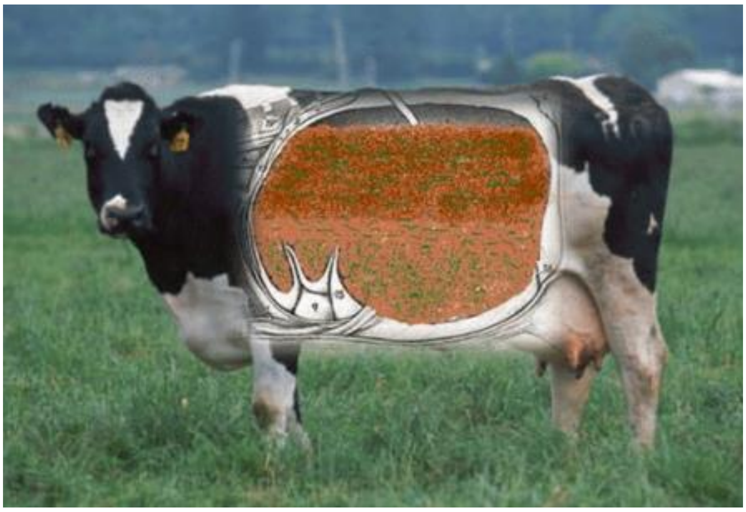

Figure 6: Image of Rumen Fill with NDF
Source: Kurt Cotanch from Van Ambrugh slides

The top layer of the rumen - 'the rumen mat' - is where the highly degradable material will be within the rumen (figure 6 above). In terms of the NDF fraction this will be the fast pool. As the rumen bugs work on the feed material the production of gas increases its buoyancy, keeping it at the top of the rumen. As the nutrients are exhausted the feed material drops to the bottom of the rumen and is flushed out. Highly degradable raw materials are broken down quickly and disappear rapidly from the rumen as the VFAs are absorbed through the rumen wall. Microbial protein is flushed out meaning higher intakes are then likely. Less degradable material will be less buoyant and will be flushed out more quickly.

Through having greater understanding of what is happening within the rumen we can, using a mechanistic model, feed protein more accurately. The model can calculate the N balance of the rumen and accurately predict AA supply in the small intestine. We are then able to supplement N and specific AA to the required level to be more N efficient.

8.0. Grass - do we fully understand it?

8.1. The role of Sulphur

In the UK we can grow grass. We have a temperate climate, and in a normal year have plenty of rainfall, which gives us the potential - with well managed soils - to grow grass cheaply and effectively. Down the western side of the UK, dairy farming is predominantly focused on grass as the major forage and feed component, either as fresh grazed grass or ensiled grass silage. Grass tissue, dependent on timing of harvest/grazing can be full of N; however, we need to understand grass and its management to fully utilise it within our diets.

Sulphur (S) and its use on grassland has been a hot topic for many years. S is vital in protein synthesis within the grass plant, plus converting the N into true protein and available AA within the cow. There are four S's containing AA: Cysteine, Homocysteine, Taurine and Methionine, the latter being the most limiting AA within UK diets. Through applying the required level of Sulphur in ratio to N in grass, true protein and - most importantly - methionine will be increased. The target ratio should be 10:1 N:S, with S content more than 0.25% DM (*CF Fertiliser, 2015*).

8.2. Grass digestibility

When looking at dairies in the States there is a perception that lucerne (alfalfa) is of a higher feed value than UK-based grass silages. When speaking to Professor Michael Van Amburgh of the University of Cornell, I soon realised how envious the Americans are of some our grass silages. Figure 7 below demonstrates the digestibility of the NDF within spring and autumn grass compared with lucerne, showing that the digestibility and the disappearance of grass is far quicker and has less uNDF : meaning there is the potential for higher DMI and performance from grass over lucerne.

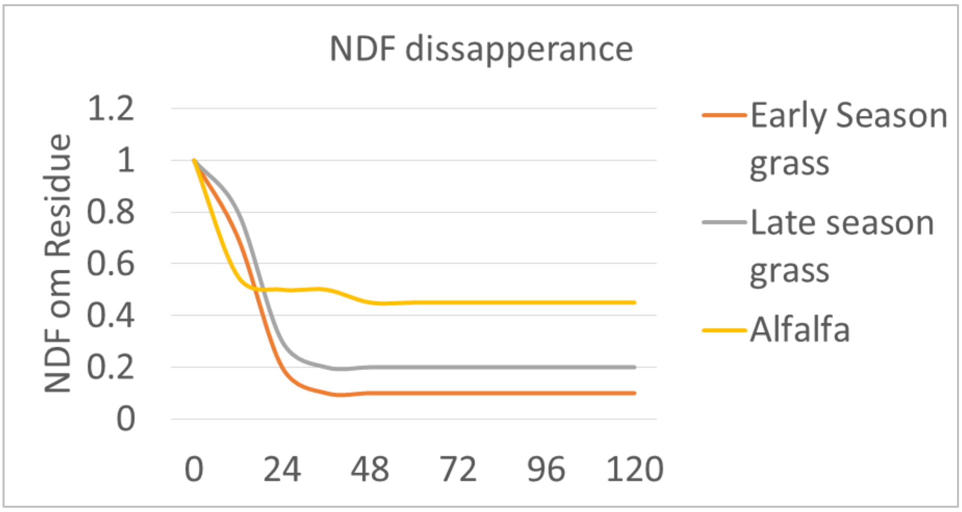

Figure 7: Difference in NDF disappearance between Alfalfa and Early and Late Season Grass.
Source Van Amburgh

In Ireland I met Michael Dineen at Teagasc, Clonakilty, who is a PhD student at Cornell. Work carried out by himself has shown the relative digestibility of fresh grass and how it reacts within the rumen. Figure 8 below shows the NDF digestibility of spring vs autumn grass.

As you can see, the spring grass degrades faster within the rumen with a higher kd (percentage of rumen outflow per hour), and showing a lower uNDF compared to autumn-grown grass. This shows how NDF as a fraction can behave differently even within plant species, dependent on the timing of the season when harvested. NDF can differ in degradation rates and how quickly it degrades. Increased degradation of NDF can affect energy supply to the cow through increased VFA production and increased flow of microbial protein, whilst also affecting DMI. It is essential that NDF is broken down into fractions in all basic feed analysis in order to be able to feed the cow more accurately.

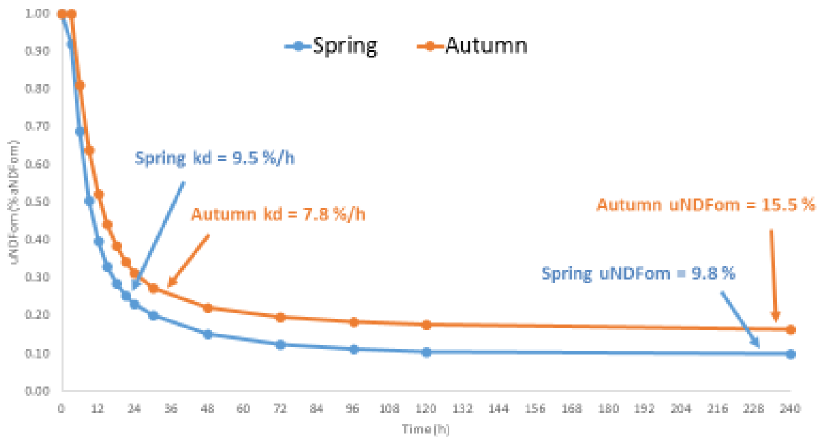

Figure 8: Comparison of Spring and Autumn Pasture in Ireland. Source Van Amburgh and Dineen Slides

8.3. Conserved grass silage

I was drawn to visit the Netherlands due to their reputation for producing some of the best grass silage in the world. They are able to produce high quality digestible forage with the potential for high forage intakes, leading to higher milk constituents and yield.

In the Netherlands, farmers have been running a multi-cut approach which is now becoming very common over here in the UK. Cutting grass through the season every 4 weeks at a very young leafy stage means as many as 6 cuts can be taken through the course of the season. This enhances the energy and protein of the grass and reduces the fibre in the form of NDF, making the silages far more digestible. This increases intake of home-grown forages on the farm, meaning less concentrates need to be purchased, including protein. Grass silage cut at 4-week intervals would act very similarly in the rumen as fresh grass. *See figure 8 above.*

Due to their climate with its lower average rainfall, farms in the Netherlands are able to produce 32-38% DM grass silage consistently between cuts. They have the opportunity to reduce wilting times and still achieve higher DM percentage, meaning more of the true protein is retained within the silage. With a higher DM, the risk of higher lactic acid is reduced, and sugar is retained within the silage; leading to higher palatability and lower lactic acid giving a reduced risk of SARA (Sub acute rumen acidosis). Due to our inconsistent weather in the UK, harvesting presents a greater challenge here, with wetter, lower DM grass silages being harvested, with lower pH and higher lactic acid. This presents a challenge as the rumen can be at higher risk of SARA, and we are forced to restrict the amount of fermentable carbohydrates (starch and sugar) that we can add to the diet to safeguard rumen health.

The target DM that UK producers need to achieve in grass silage is 30-35%. Industry standard and best practice would be to recommend the use of a homofermentative bacteria as an additive. This would increase the production of lactic acid and make the silage more stable and reduce shrink (waste). When we have high lactic acid silage, we have to reduce starch and increase digestible fibre which may reduce microbial protein synthesis. However, if it can be seen that the silage will be harvested below the target DM, heterofermentative bacteria additives that change lactic acid to a weaker acetic acid may be an option to reduce acid load. When using L. buchneri on grass silages, a proportion of the lactic is converted into acetic acid. Propylene glycol is also produced as an intermediate which can be used by the cow as a glycose precursor. There is a DM loss associated to this process but the advantage is that lactic acid in grass silages would be reduced.

8.4 Grazing grass

Grazing grass isn't always as straightforward as it seems. Feeding grass on its own can be limiting as there is too much N within the diet and a limitation in fermentable carbohydrates. One way in which to increase microbial protein yield and increase rumen N efficiency would be to dilute the grass down with a lower N feed source which is high in fermentable carbohydrates - such as maize silage or fodder beet.

I met with Sophie Prendergast who completed a PhD at Lincoln University in 2014. The work she carried out showed the difference in steers fed on a low CP diet of fodder beet versus a higher CP diet fed on ryegrass. The work showed dry matter intake and microbial protein supply to the steers was higher in the fodder beet treatment than in the grass treatment. The fodder beet supplied almost twice as much microbial protein despite a lower CP content in the diet. The lower CP content and very low concentrations of rumen ammonia did not reduce microbial protein production, which would have been expected. A hypothesis on why this happened is that it could have been due to an adaptation in greater nitrogen recycling; showing how a lower CP diet can become more efficient through the recycling of N in the saliva.

The benefits of grazing grass and feeding fodder beet is the low DM content of the feed; meaning that there is more water entering the rumen. The water within the rumen is quickly absorbed and epithelial blood flow is quicker - carrying more VFAs from the rumen faster, thus preventing SARA and increasing intakes.

Work carried out by Dairy NZ at Canterbury showed that the use of plantain and chicory helped to reduce N concentration within the urine. Plantain and chicory have a diuretic effect due to their high mineral content, which causes the cow to urinate more. There would be more patches of urine in the paddock, but the total amount of N excreted would be the same. Rumen N efficiency would not be affected.

In Lincoln University, NZ, I met Dr Benrnadit Saldias, who in 2014 wrote a paper on the daily variation on rumen fibre (NDF) disappearance in lactating grazing dairy cows through the grazing season. In the trial, 24-hour interval paddocks were allowed daily and entered after PM milking. During the trial it was observed that a cow could clear 75% of her allocation of DM of grass from 5pm until dusk (4 hours post the afternoon milking). Low rumen pH was observed 8 hours post grazing - as low as 5.2pH. Rumen fill changed dramatically from 1 hour post grazing until morning, showing that grass rapidly degrades and disappears within the rumen. Dr Saldias also observed that spring and autumn grass reacted very similarly within the rumen, with a higher disappearance rate compare to mid-summer grass. This shows mid-summer grass could also be of poorer quality in UK diets.

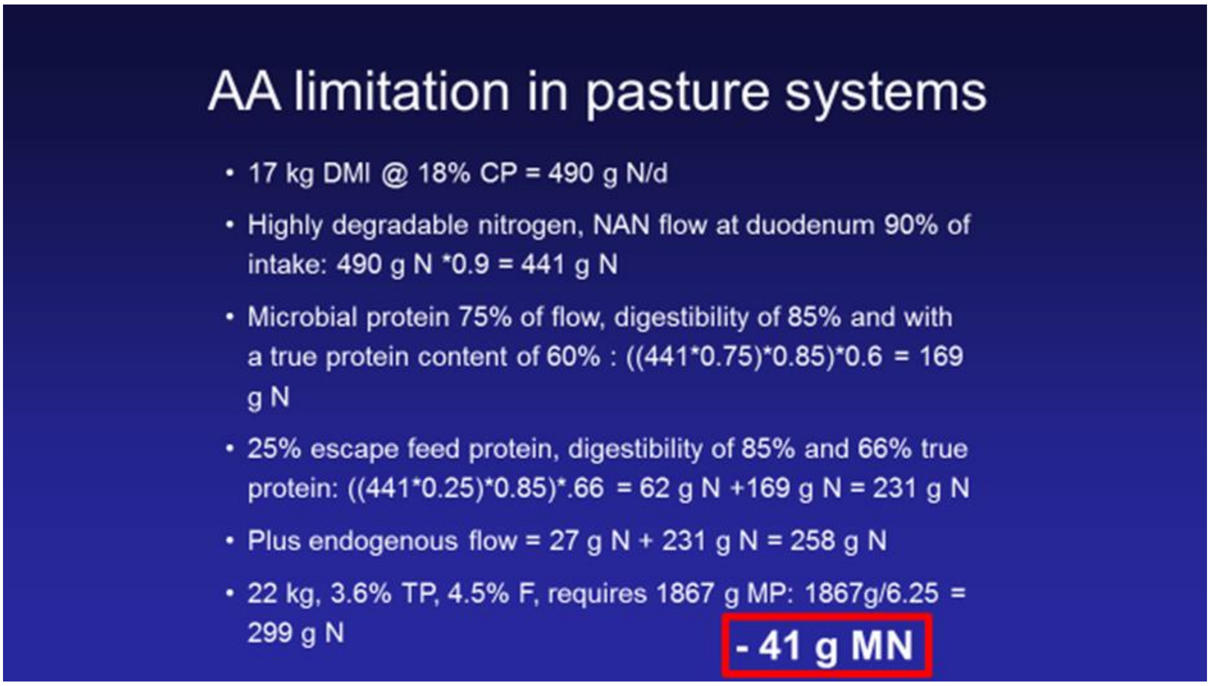

Figure 9: AA limitation in pasture system (*source Dineen Personal Communication*)

When we are grazing grass we are overfeeding CP, but we can also be underfeeding MP and AA which could restrict performance. Calculations by Michael Dineen at Teagasc (figure 9) shows the N intake of a cow eating 17kg DM of grass, which is 18% CP. His work shows that a cow on a grass-based diet can be -41 g Microbial N of her requirement for 22kg milk at 4.5% fat and 3.6% true protein. This shows the supplementation of rumen bypass protein or targeted AA could boost milk yield and quality off the same DMI.

9.0. Cow health, fertility and performance

9.1. Milk Urea Nitrogen (MUN)

As I set out in my objectives, cow health and fertility can be compromised when fed on high CP diets. If the rumen isn't in balance and there is too much ammonia and insufficient energy, ammonia will build up as it passes through to the bloodstream. Ammonia is toxic to ruminants so is converted to a urea in the liver.

Biswajit Roy et al. (2011) studied milk urea concentration and how this could be used for management decisions. it was concluded that three general mechanisms were proposed to describe how excess dietary protein may negatively affect fertility:

- Nitrogen by-products may alter the uterine pH and mineral balance.
- Nitrogen by-products or efficiency of energy utilisation may alter gonadotropin and (or) progesterone secretion.
- Toxic by-products of nitrogen metabolism from the rumen (ammonia) and liver (urea) may impair sperm, ova, or early embryo survival.

The urea level within milk can be calculated, and this is an indication of the ammonia which escapes the rumen. This is measured as milk urea nitrogen (MUN) and can potentially be used as a management tool to control the protein status of the diet on a regular basis.

Farms across the world receive this figure either weekly or with every load of bulk milk sent to the processor. Although MUN will change due to stage of lactation and age, it is still a good guide if individual cow data is not available.

MUN is expressed in different ways across the world. For example, a MUN of 20mg/dl would be expressed as:

Urea mg/dl	Urea mg/litre	Urea %
20	200	0.02

In the States the target for MUN was targeted at 8-12mg/dl, which is far lower than what we see in the UK (20-30mg/dl.) However, with lower CP diets this was to be expected. US producers associate higher MUN with poorer fertility. *Rajala-Schultz et al. (2001*) showed herds in Ohio, US, indicated that increasing MUN levels appear to be negatively related to dairy cow fertility and are associated with a lower risk of detectable pregnancy at herd checks.

In Australia, reporting MUN was a new concept and they hadn't been using it as a management tool thus far. As they were grazing higher CP pasture, MUN levels were typically between 30-40 mg/dl, but would also peak during some periods of the year when grazing Lucerne.

In New Zealand MUN analyses typically ran between 30-40mg/dl on pasture diets. However great fertility performance was very good: a 10-12% empty rate at 12 weeks.

Prof Jim Gibbs from the University of Lincoln, Canterbury, New Zealand, explained that the New Zealand diet is based solely on grass, as grass leaf tissue is full of N, therefore full of protein. This means if urea fertiliser use is limited they will grow less grass which is counter intuitive. In New Zealand they don't care about protein as there is plenty in supply from their cheapest feed source. Feed is purchased in NZ on a cost per kg/DM, based on energy with no thought on CP. Diets in the States and Europe are different as they can be deficient in N, and protein is more expensive to buy onto the farm.

The rumen can deal with any diet as long as the change is carried out slowly. Grass during periods of the year can be high in sugars and low in NDF, leading to a potential of SARA. A rumen pH of a grazed cow can be consistently as low as 5.2pH (*Saldias, B., 2014*), with no adverse effect on health or performance. Similarly, with high N grass diets the liver is able to function and cope as long as there are no sudden changes to the diet. If rumen ammonia levels are kept constant there should be no adverse effects on fertility.

To summarise, it is clear that high MUN does have a negative effect on fertility; but possibly in high yielding cows with high DMI, the liver cannot process all the ammonia and therefore the stress on such a cow is much higher. On lower yielding grass-based herds in NZ, MUN is far higher but achieving empty rates of 10-12% in 12 weeks, suggesting MUN doesn't seem to have a bearing on fertility. MUN can clearly be managed and cow type and performance does make a difference. The message here is that consistency is key.

9.2. Consistency is persistency

It must be noted here that dairy cows want consistency. They want a boring life!! Any changes to management can disturb and affect performance; this includes any changes to the diet. The target is for a lactation curve to be persistent and maintain a high yield into late lactation. The rumen microbial population is very sensitive and sudden changes in the diet can cause certain bacterial populations to die off, whilst other bacteria will multiply depending on the changes. During this interim period, which takes 2-3 weeks, there can be a loss in performance as well as strain on the immune and reproductive systems.

The cow's performance and ability to react to changes will differ depending where she is on her lactation cycle. During the period when milk yield drops, mammary cell death occurs. During the beginning of lactation leading up to peak yield the cow has the ability to regenerate these cells if the cause of milk drop is not sustained over a long period. However, post peak yield she will not recover from any changes or drop in milk performance, meaning that yield will be lower from then until the end of lactation. For example, when changes of silage clamps happen.

When diets are consistent, the microbial population can become more efficient at producing VFAs and microbial protein from the same DMI, which increases feed efficiency. The key message here is that 'consistency is persistency'.

A diet formulated on paper isn't always the diet that is fed to the cows. Management and feed out are key contributors to maintaining consistency on the farm. Monitoring DM of forages and having a well processed TMR is vital to maintain the intended feed diet.

As I saw from the work carried out at Cornell and Teagasc (*Figure 9*), grass NDF digestibility alters as we go through the season.

When feeding from clamped silage, cows can encounter material from different cuts, so during the feeding period there are multiple changes within the diet and the potential milk yield is compromised accordingly.

During my visit to the Netherlands, I saw some great forages and performance, but what struck me most was their attention to detail at ensiling, thinking right from the start about feeding and performance issues. A typical dairy in the Netherlands would have two robots and 120 cows. They would have 5 small silage pits with walls no higher than 6'. When filling the clamps through the season, they would put a layer of the first 4 cuts in 4 of the clamps, leaving the 5th and 6th harvest in the 5th clamp for the youngstock. This is called the Lasagne effect and is a tool to feed out the earlier cuts in the season more consistently (figure 10).

This is something UK producers need to think about when laying out and filling silage pits through harvest as it limits diet changes and ensures cows can be fed earlier cuts of silage all year round.

Figure 10: Lasagne effect of layering cuts of grass silage

10.0. North American diets

During my Nuffield Farming experience I had the opportunity to go to the States, visiting upper New York State and Wisconsin. These two States are well known as two of the great dairy States in America.

Figure 11: Me at Rosendale Dairy, Milk Source, with Herd Manager Pedro Ibarra-Cortes (right) and representatives from Feed Components Tiago Barros and Sarah Schmitz. Milk Source milk 38,000 head over 7 sites.

In the upper north east States, with warm summers and very cold winters, the dairy industry has evolved to larger herds being housed 365 days a year. The dairy diets in these regions are fully TMR-based, made up of maize silage and alfalfa/lucerne in the form of haylage or silage. Diets and formulations are similar from farm to farm, and this is mainly due to the consistency of maize silage from year to year.

Forage makes up 60-70% of the diet, with 60-70% of this coming from maize silage. The herds were constantly performing at 40-45 litres/cow/day, with many boasting the 100lb/day which all farmers target.

These regions can grow vast, consistent crops of maize silage – these are predominantly GM, and are bred to increase their digestibility traits and allow for higher starch and fibre availability in the rumen. Brown mid-rib corn silage (BMR) was often selected for its lower lignin and stalk percentage, making it more digestible with a lower NDF content, meaning higher DMI of forage could be expected.

With consistent and ample digestible maize silage within the diet, this can pull the N intake of the diet right down. Also, with a high starch content adding a slow fermentable carbohydrate to the rumen, we can expect higher microbial protein yield, showing far more efficiency in N utilisation within the rumen. *(continued 2 pages further on, after the 2 photographs)*

**Figure 12: GM Maize with black grain -
it doesn't enter the human food chain.**

**Figure 13: Matt Koiman, Consultant for VitaPlus,
chopping maize for DM test pre harvest**

Rumen degradable protein is available through the lucerne. Protein supplementation in these diets is supplied mainly with soybean meal. Most of this will be bypass-heat-treated soybean meal and bloodmeal - which again is high in bypass protein - along with distillers' grains and also other various by-products. (Bloodmeal is not authorised as feed in the EU). With a low N base diet which is high in fermentable carbohydrates and supplemented with some rumen degradable protein, microbial protein synthesis yield is high and utilises the N available efficiently. For these high performing animals extra bypass protein is required to boost MP (metabolisable protein) supply in the small intestine. At this time the AA profile of the diet is calculated, and extra methionine and sometime lysine is supplemented.

Case Study: Dr Bill Prokop - Cornell University Farm

Dr Bill Prokop is a vet and consultant and manages the Cornell University dairy. The attention to detail was phenomenal, producing milk very efficiently.

- 580 cows AYR milking 3x
- Av 850kg mature bodyweight
- Producing 98 lb/day milk (44.5 kg/day)
- 3.8% BF 3.3% P
- Average DIM 160
- Average rolling pregnancy rate 36%
- 65% of the diet is forage
- 70% of this is maize silage (BMR and conventional)
- Alfalfa and Triticale wholecrop makes up the rest of the forage
- Total TMR/kg DM at:
    - 28% starch
    - 9% Sugar
    - 15.4% CP
- MUN running between 8-12mg/dl

Figure 14: Happy cows at the Cornell University Farm

Rick Schwenk- Lake Breese Dairy Group

Although the average herd size in Wisconsin is still 142 cows, larger dairies and consolidation was the path many producers were taking to be able to justify new investment. The ration for the cows on this farm was, however, typical of Wisconsin dairying in general.

- 3300 cows AYR milking 3x (2850 cows in milk)
- 92lb/milk day (42 kg/day)
- 26kg average DMI
- MUN 9-11 dl/mg
- 2800 acres maize silage as shredlage
- 70% BMR (Brown Mid-rib)
- 30% conventional
- An additional 2300 acres for Alfalfa and heifer rearing
- 67% forage in the diet
    - 65% maize
    - 35% Alfalfa

Figure 15: One of 4 cubicle barns at Lake Breeze

11.0. Making the most of your assets

11.1. New Zealand

The majority of countries that I visited across the world had experienced high land values. They saw their land as the biggest asset on their farm, which it rightly is. It is essential to maximise DM yields/ha and make the most of homegrown feed.

The common stereotype of a Kiwi dairy farmer is that they are focussed on milk from grass and are unwilling to supplement. Although I came across many farmers with this mindset, I felt there was a certain shift in opinion. With land prices soaring and farm debt already high, many dairies are now trying to produce more from the land they already have by increasing stocking rates and supplementing either by installing parlour feeders or constructing a feed pad.

Working out your stocking rates and the potential DM you need to purchase is what drives success. In Taranaki the annual expected growth of grass can be up to 16-17t DM/ha. I came across two equations there that gave similar results when working out the required DM per head:

- 85kg liveweight will require 1t DM - 500kg cow would require 5.9t DM
- 12kg of DM per kg of milk solids - cows producing 480kg MS would require 5.8t DM
- 2.9 cows ha - grass only
- 3.5 cows ha - 1t purchased DM

Grazed grass would be the cheapest feed per T/DM; however, some dairies in the State were able to increase profitability per ha by increasing stocking rates and purchasing DM in the form of dry feed, or growing maize silage which yielded higher DM yield/ha. Below is an example:

Case Study: Steve and Maria Poole, Taranaki

- 820 cows spring calving
- 16% empty rate at 11 weeks
- Stocking rate 4 cows/ha
- Target 2100kg MS/ha
- Growing 17t/ha of grass
- Growing 22ha of maize silage at 22t/DM/Ha
- Purchasing 1,280t DM of Palm Kernel, soya hulls, distillers' grains and a whey-based liquid

By utilising grazed grass within the diet to its full potential, Steve and Maria Poole also grew maize silage as it gave a higher yield per ha only costing 14c/kg/DM, compared to the next cheapest feed stuff such as palm kernel at 20c/kg/DM. Feed was offered on the feed pad before afternoon milking.

(*see photo overleaf*)

Figure 16: The Pooles' cows grazing with Mount Taranaki in the background.

Case Study: Balle Brothers' Dairy, Kopuera, near Auckland

I was shown around the Balle Brothers' dairy, Kopuera, near Auckland, by their nutritionist Paul Sharp. The Balle Brothers run a vegetable growing business and purchased dairies across the region to make best use of the waste vegetables. The waste of potatoes and carrots adds starch to the diet and onions add fibre: with all three being low N products this is a great supplement for grazed grass.

- 1100 ha upland dairy farm
- 2700 cows (split in 6 herds- 4 spring and 2 autumn)
- Producing 1.2 million tonnes of milk solids
- 3 x 50-point rotary parlours
- 2 x 500 cow feed pads
- Feeding 3t DM/cow/year of waste vegetables
- MUN running at 12-20

(continued overleaf)

Figure 17: Vegetables supplemented the feed

11.2. Brazil

At the international Nuffield Farming Contemporary Scholars Conference (CSC) in Brasilia, Brazil, Simon Wallace from Lettissimo Dairy described Brazil as a 'biological Ferrari' with an abundance of sun, water, tropical plants and the development of technology. Although I didn't have the opportunity to visit the dairy, Simon, from New Zealand, who had set up in the State of Sao Paulo, spoke of the potential for producing milk in Brazil. The land could potentially grow 40-45t DM/ha, allowing stocking rates to be increased to 10 cows/ha and produce 45,000 litres/ha on a grass-based system with 900kg of supplementary feed, mainly maize. The farms were set up on 56ha circular irrigated plots, with 550 crossbred cows on each plot, (currently totalling 11 sites) and could grow grass consistently all year round.

This shows the potential land has in various parts of the world. There are huge opportunities to increase DM yield on UK farms, with many farms able to achieve 15+t DM/ha. Many at the moment achieve no more than 10t DM/ha so there are huge opportunities there to increase DM/ha and reduce the need for bought-in feed – or, alternatively, increase stocking rates.

12.0. Producing milk in challenging climates

12.1. Dubai

When passing through Dubai I had a great opportunity to visit Al Rawabi Dairy, a dairy in the middle of the desert with a herd of 7,000 dairy cows, and another 5,500 followers on the farm. Whilst producing 185,000 litres of milk a day the farm was fully integrated with a processing plant on site which bottled the milk and produced yogurt and milk-based drinks.

There was no feed or forage produced on the farm: instead all feed was imported onto the farm. They sourced feed from around the world, with Dubai itself producing only the molasses.

- 1,200t of hydrated maize silage was imported monthly from Lithuania.
- 450t of lucerne hay imported monthly from Sudan, Spain and Argentina.

Other raw materials imported from all over the world included maize grain, soybean meal and distillers' grain. Up to 15kg of water/head/day was mixed into the TMR to increase palatability.

As they were milking in hot and dry weather conditions, with temperatures soaring to between 35-45˚C, heat stress was obviously an issue. However, good management and practices ensured cow health and welfare was of the highest standard.

Figure 18: Imported forage at Al Rawabi Dairy

I couldn't help but notice when looking around the dairy that there were huge environmental concerns attached to importing feed from around the world into a desert; and also that producing a product such as milk was not the most logical idea. With the cost of production at 42ppl, importing milk from countries who have the forage, climate and infrastructure to produce milk more efficiently with a lower carbon footprint would be the way forward. It's clear to me that the UK is in a stronger position to produce milk efficiently and sustainably than many other countries across the world due to the forages we grow. The UK needs to use this to our advantage.

12.2. Victoria, Australia

Dairy farming in Victoria, Australia, can also become very challenging due to severe weather conditions. However, good grazing management and growing alternative crops allows herds to be outdoors 365 days of the year. With hot dry summers and wet winters, grazing rotations and seasonal calving are key to their success.

Figure 19: Attending a discussion group meeting in Warrnambool, South Victoria

Case Study: Matthew Glennen, South Victoria

- 300 autumn calving cows
- Producing 600kg/MS/cow annually
- Stocking rate 1.8 cows/ha
- Growing 9t DM/ha annually
- 25ha of maize silage grown
- Purchasing 200t of vetch hay
- 600t of wheat and canola meal

Calving down in a 12-week block starting in March, there is no grass for the cows until mid-April. During this time, they are fed on the ration shown on next page:

- AM Milking - Grain mix of wheat and canola
- AM - Fed maize silage on the feed pad
- PM - Then go onto the summer crop- Stubble Turnips
- PM Milking - Grain mix of wheat and canola
- Night - Grass silage and vetch hay at night- access to shaded sacrifice paddock.

Then, once grass starts growing, they will be on grass reaching peak. As grass slows down in the spring, cows dry off and are fed grass silage.

Figure 20: Matthew Glennen (left) and agronomist Daniel Meade NSch (right) checking maize germination

The logic behind this is to match the energy up with protein in early lactation to provide as much glycogenic energy as possible: providing starch from the maize silage and wheat, and sugar from the fodder crop before supplying the protein in the vetch hay.

In north Victoria, summers were more challenging with higher temperatures and drought. It was common to irrigate grazing and crop paddocks by the flood method. This allowed farms to run two calving blocks. As perennial ryegrass would struggle to cope with the heat, annual ryegrasses were sown each autumn and supplied grass from autumn to spring. During the summer crops such as lucerne and millet were grown and grazed.

Feed wheat is a very cheap commodity in Victoria and, as growing crops for grazing can be a challenge, the DM void in the diet is filled with concentrates; predominantly wheat for starch and canola/rapemeal for protein. It's been historically seen in the UK that feeding more than 4kg of wheat a day has a negative impact on a cow mainly due to increasing its acid load and causing SARA. In this region upwards of 8kg/day are fed to cows with no health issues or cases of acidosis. This has helped as it is a harder wheat and degrades more slowly in the rumen. Some farms may use Eskalin in their mineral premixes. It is an anti-infective and is effective in reducing liver abscesses in diets pushed with starch; but Eskalin is prohibited within the EU. This makes me question: are there opportunities to feed more wheat within a UK diet? The answer is yes but we need to understand our NDF.

Although dairy farmers in Victoria were innovative in their management, efficiency and nutrient management were to some degree their downfall. To get an increase in DM yield, dairies would use up to 300-400 kg/N/ha with limited responses in growth. Milk urea levels run consistently at 30-40 mg/dl with no intention of looking to reduce N intakes to increase N efficiency within the rumen.

Grazing lucerne poses other risks. For example, high CP means high ammonia levels in the rumen. As can be seen in figure 21 below this causes high rates of urea in the urine, which can then burn paddocks and limit growth. The loss of N to the atmosphere also poses huge environmental issues.

Figure 21: Burnt patches of Lucerne across the paddock due to high urea in the urine.

13.0. Breeding for feed efficiency

During my Nuffield Farming experience I have spoken about increasing rumen N efficiency, but what about looking at total feed efficiency?

Producing more product per kg of DM would suggest lower methane output per kg of product. Methane is one of our biggest environmental concerns and so a lower output would be far more sustainable. Ultimately if we can produce more for less it would have substantial financial benefits.

In the UK we have a range of different breeds and genetics, ranging from the high producing 700-800kg Holstein to the 450-500kg Kiwi crossbred grazing cow. However, we must make sure we have the correct cow for the system we are trying to run on our own individual units. There is a strong North American Holstein influence within UK herds. However, our diets do not reflect those fed in the States, as we rely on grazed grass and grass silage for a good proportion of the intake. So, this begs the question: do we have the correct cow in the UK?

During my time in Green Bay**,** Wisconsin, I visited a 6000 cow herd, Pegels, Ponderosa Dairy, milking crossbreds on an all-year-round indoor system. The herd had the influence of 2/3 Holstein genetics and 1/3 US Jersey genetics. Here I found two herds differing genetically and producing similar yield at very different efficiency rates (*See Table 2 on next page*). The crossbred herd achieved lower yields, but equal MS output from 2.5kg less DM/cow. With a cost of a kg of DM in the UK at 16p/kg this would be a saving of 40p/cow/day or £14,600 a year over 100 cows, to produce the same MS. With the same level of CP% within the diet the crossbreds had a 3% higher nitrogen efficiency of converting intakes of N (feed) to output of N (milk protein).

Figure 22: Cross bred cows at Ponderosa Dairy.

Table 2: ***Comparison of Crossbred and Holstein herd production outputs***

Measurement	Crossbred	Holstein
Weight (kg)	630	800
Milk Butterfat (%)	4.2	3.6
Milk Protein (%)	3.4	3.1
Yield (litres/cow/day)	38	43
Milk Solids (kg/day)	2.9	2.9
DMI (kg/day)	24.7	27.2
N Efficiency (%)	31	28

With the demand for higher milk solids in the UK dairy industry, could crossbreeding present a viable option to produce a more efficient cow? Rearing a smaller cow with a lower maintenance cost, producing more kg's of milk solids, whilst eating less dry matter and also meeting the processors' demands for higher milk solids, would mean less water was being carried around the country. This in return would reduce manure excretion and pose less of an issue in regard to exporting unwanted manure off the farm. The biggest benefit would be producing as much product (kg's MS) for less input.

Staying with the theme of cross-breeding, I also took the opportunity to visit Leachman Cattle of Colorado – a company built by Lee Leachman that has developed and bred the Stabiliser beef breed. The company markets over 1500 bulls/year, using their own $Profit figures to sell the bulls on their projected progeny performance. The bulls are bred for feed efficiency (DM to kg/LWG,) trialling the bulls on feedyard monitoring gain and intakes, with this equating to the associated $Profit figures.

Figure 13: Bulls for sale at Leachman cattle of Colorado. Source: author's own

Can the dairy industry learn something from this through producing a composite breed that can retain highbred vigour and increase feed efficiency? And is there an option to breed a line of F1's (first cross) that will retain a higher percentage of highbred vigour?

14.0. Discussion

14.1. Low protein diets in the UK

Through extensive travel and information-gathering it is clear the UK has a long way to go to reduce overall protein feeding and become more efficient in terms of rumen N utilisation. From the information I gathered over in the States it is clear that running a low N base diet can be effective in producing high yields. In the UK diets are predominantly based on grazed grass or perennial grass silage, which are high in N, and low in fermentable carbohydrates. The Americans see our cows as thin hat racks, with no rumen fill exactly for this reason. We can make the excuse that the States has different and better quality forages. However, we just need to understand our forages better and feed accordingly to maximise microbial protein yield.

14.1.i. NDF pools

To understand our forages, we need to understand our fibre and NDF pools. *(See Chapter 7.2).* If UK-based diets are short of fermentable carbohydrates we need to balance the fibre pools, so we do not cause SARA. When we take something out of the diet to add starch or sugar in, it will usually be fibre. The key is to maintain NDF at the required rate for adding starch and sugar.

We can also look at supplementing our NDF within our very fast pool early season grasses or grass silages. Nutrionally Improved straw (NIS), which is pelleted straw treated with sodium hydroxide, could also be a viable option. The sodium hydroxide breaks the crosslinks within the straw and turns a feed material which is high in uNDF to contain more slow-pool NDF. This may have a positive effect in keeping the rumen fuller for longer as the very degradable fast pool disappears very quickly.

Balancing the NDF pools will give the opportunity to control intakes and efficiency to maximise output and production from the DM being fed.

14.1.ii. Fermentable carbohydrates

In most cases the limiting factor within the rumen for limiting microbial protein synthesis would be fermentable carbohydrates.

It would be great to increase maize silage in the diet to raise the base level of starch, but unfortunately many farms can't grow, or can't grow enough, consistent maize, due to marginal land plus the inconsistency year-to-year of the crop, making it too expensive to grow. Growing maize year-after-year with the land left open over winter can be concerning for nutrient loss and leaching.

The problem with pushing too much fermentable carbohydrates into our cows' diets is probably due to our high lactic acid silages. Due to our inconsistent weather in the UK, harvesting presents a greater challenge, with wetter, lower DM grass silages being harvested, with consequent higher pH and higher lactic acid. This presents a challenge as the rumen can be at higher risk of SARA and we are restricted on the amount of fermentable carbohydrates (starch and sugar) we can add to the diet.

In terms of starch, wheat is the most cost effective and readily available form, but with the negative problems associated with feeding too much wheat, diets rarely reach the levels of starch required to increase microbial protein yield sufficiently. We could see in section 12.2 that in Australia it was common to feed 8kg of wheat to cows over two feeds and with no adverse effects. By understanding our NDF fractions we could increase our wheat levels.

Feeding ground maize meal has become very popular over the last few years as it has become more in line with wheat prices. However, the hard maize grain imported from Europe has poor digestibility and can be seen passing through the cows, leading to lower than expected microbial protein yield. Fine grinding could help but, as Dr Bill Prokop from Cornell University farm explained, heat treating maize could be the way forward to increase availability in the rumen.

We cannot forget about sugar! Sugar is a valuable component of any diet and increasing sugar in the diet can lead to an increase in microbial protein yield.

14.1.iii. Supplementing protein

Microbial protein synthesis needs to be the driver for metabolisable protein supply to the small intestine. The rumen needs to be fed rumen-degradable protein when required to achieve this. If rumen energy and rumen ammonia are as close in synchrony as can be possible, supplementation of bypass protein needs to be considered. When asking Prof. van Amburgh what is missing currently in UK ruminant diets, he replied: '*The UK don't use enough rumen-protected soybean meal*'.

It will be crucial going forward to formulate diet on AA supply and shortfall to realise the potential of the cows we are feeding.

Although we in the UK are trying to reduce imported soya bean meal intake, we can add rumen bypass protein in the form of protected soybean meal to match MP (metabolisable protein) requirement on top of the microbial protein which has been supplied from the rumen. Although the feedstuff would be more expensive, we can reduce total protein cost and be more efficient in the N we use. As an alternative to protected soybean meal we could supplement formaldehyde-treated rapeseed meal: this could be more cost effective and produced from UK- or EU-sourced rapeseed meal.

Once the rumen and MP supply have been balanced we can then look at AA and supplementing where required. Most UK diets will be deficient in methionine and, depending on yield aspirations, should be supplemented accordingly with ME supply. It will be crucial going forward to formulate diet on AA supply and shortfall to realise the potential of the cows we are feeding.

Feeding high CP grass or grass silage could mean there is enough CP. However, increasing bypass protein and supplementing AA can increase performance (as seen in Figure 9). With reduced use of CP on farm in the UK I have seen an initial saving of 0.3-0.5p/litre on feed costs. This equates to £4,000/year for every 1,000,000 litres sold; and this does not include benefits of higher health status and reproductive performance which will increase yield and dilute feed costs down further.

14.2. Total farm efficiency

14.2.i. Land

During the course of my study and travelling, it's become clear that we need to rethink our strategies as dairy producers and structure a more sustainable business that is both sustainable to the environment as well as a business model that is able to withstand volatility in our markets.

Land is our biggest asset on the farm: we need to ensure we use it to its full potential. Ensuring soil health and fertility is paramount to achieving high DM yields whatever your crop may be. When we look at stocking a farm we must evaluate our stocking rate, either on a grazing system or high yielding housed herds. Getting the stocking rate right allows you to make the most of homegrown forage or feed, and limit the amount of feed which is bought in.

As we think about purchasing dry matter (DM) for the farm, we have to think where the waste produced from that DM - in terms of slurry and FYM - will be applied. If bringing in possibly 70% of the DM that a cow eats - either in the form of concentrates, moist feeds or purchased forage - we have to think about where the waste will then go. In the majority of cases it does not return to the point of origin, meaning there is an imbalance in nutrients supplied back to the soil. This usually means that waste such as slurry and FYM is spread on a restricted area. This increases the risk of leaching as well as making the land sour, restricting performance and unbalancing the health of the soil.

14.2.i. Feed efficiency

In this report I have spoken at length about N efficiency; however total feed efficiency needs to be considered first.

Feed efficiency is closely correlated with management factors such as housing, feed space, lying surface, standing times, lameness and access to feed. There are other lesser factors as well. As I mentioned, a cow likes consistency in her routine and if we can achieve a high standard in the factors just mentioned, we can increase feed efficiency, producing more product from the same amount of feed.

If we can get a cow to produce more milk/milk solids from less DM, this means the cow eats less DM/kg milk solids, meaning less faeces per kg milk solids, meaning less slurry and FYM that needs to be spread back out on the land. If we can also run lower CP diets, increasing rumen N efficiency, we reduce the risk of ammonia and nitrous oxide emissions. Storage and application of slurry and FYM has a further role to play in reducing emissions.

to breed a cow suitable to your farm is essential. Having a cow with a lower maintenance cost of energy and protein, but producing high milk solids yields whilst eating less DM, can be the key in increasing feed efficiency and profitability.

As discussed in section 13.0 looking at on-farm breeding policies, to breed a cow suitable for your farm is essential. Having a cow with a lower maintenance cost of energy and protein, but producing high milk solids yields whilst eating less DM, can be the key in increasing feed efficiency and profitability.

The majority of methane emissions from cattle are a result of fermentation in the rumen which is released to the atmosphere through eructation. Dairy farming contributes 20% of total global GHG emissions from the livestock sector, with methane being the largest source at 39% of dairy emissions *(Gerber et al., 2013).*

> *Supplementing our forages with concentrates or other feeds and increasing output of milk solids is important for environmental sustainability.*

Fermentation of forage fibre is associated with higher methane production in the rumen. However, starch digestion in the rumen is associated with a reduction in methane production. Looking to improve feed efficiency can decrease methane output per kg of product. High grass-forage diets would produce higher methane output per kg of product compared to diets with more concentrates or starch-based forages. Supplementing our forages with concentrates or other feeds, and increasing output of milk solids, is important for environmental sustainability.

To summarise, we need to increase feed efficiency to produce more product from less DM. Reducing the maintenance cost of energy and protein in the animal by producing more product per animal is key. To have a sustainable industry for the environment and safeguard farm businesses there needs to be a balance between performance, cost of production and emissions.

15.0. Conclusions

1. The UK dairy industry needs to be proactive in reducing ammonia emissions. Total N farm efficiency needs to be looked at in greater detail. Reducing N emissions through lower CP diets will be a great start.
2. We need to forget about Crude Protein (CP) and focus on formulating diets for Metabolisable Protein (MP) and Amino Acid (AA) to achieve optimum performance and efficiency
3. We need to understand our feed and forages better. More accurate analysis of NDF is crucial to understanding how we formulate diets.
4. The UK is able to grow grass and plenty of it; let's use that to our advantage.
5. Look to develop UK-grown protein sources.
6. Consistency of management and diets is key to looking after herd health and fertility as well as performance.
7. Increasing total feed efficiency is key to improving margins on farm as well as reducing environmental risks.
8. To increase feed efficiency, looking at the breeding of your herd could increase efficiency depending on what your system type may be.
9. Before looking to purchase feed onto farm, you need to realise the potential of your farm and whether you can increase DM yield and performance from homegrown feed and forage.

16.0. Recommendations to Industry

1. To increase total N farm efficiency, levels of bought-in protein need to be reduced
2. We need to get away from Crude Protein as an industry standard figure and place more emphasis on expected performance and N utilisation.
3. Formulating diets to balance AA, whilst monitoring rumen N efficiency, needs to be adopted on farm.
4. We need to understand our forages better and have a more detailed analysis showing the breakdown of parameters, especially NDF, within the rumen. This will give us a more accurate indicator of VFA and microbial protein production.
5. Using the CNCPS model could be more accurate in predicting performance and N efficiency on farm.
6. Need to look at farm type and breeding programme.
7. Land is our biggest asset, we need to realise its potential.

17.0. After my study tour

While conducting my study tour I've seen a wide range of farm types in various different climates. I've gained a great deal of knowledge and experience not only around my subject area, but through all agricultural industries, which has given me confidence to express my thoughts and concerns across the dairy industry.

Within my day-to-day job at Wynnstay Group PLC, I have been able to work with other members of the dairy technical team in improving our offering to our dairy customers, focusing on diets formulated to MP and AA, increasing rumen N efficiency, and improving health and fertility on farm. We are actively formulating diets to lower CP and achieving great results on farm. Although a feed compounder, the focus is still on homegrown forage and how we can get the most out of what we can grow on farm.

I have adopted and started to use the CNCPS model to assess and formulate diets on farm to balance MP and AA, which has seen an increase in performance whilst reducing both protein intakes and feed costs.

Wynnstay has also become a partner, with myself representing the group, in the CowficieNcy Project which is an EU-funded project dedicated to improving N use efficiency in milk production. The project is in partnership with:

- Aberystwyth University, United Kingdom
- Universidad Autonoma de Barcelona, Spain
- Agricultural University of Athens, Greece
- TEI of Thessaly, Greece
- University of Parma, Italy
- Noutria Hellas, Greece
- RUM&N, Italy
- Mole Valley Farmers, United Kingdom
- Laboratorios Karizoo, Spain
- Cornell University, United States of America
- Liverpool University, United Kingdom

The objective of the project is to explore models and nutrition management in order to improve profitability and nitrogen use efficiency on dairies. The focus is on both the replacement heifers and the lactating cows.

I look forward to sharing my experiences and findings with the industry: promoting the dairy industry to be proactive in safeguarding the environment by improving N-use efficiency in milk production, whilst at the same time making businesses more sustainable and profitable.

Iwan Vaughan

18.0. Acknowledgements and Thanks

Firstly I must thank the Nuffield Farming Scholarship Trust and all involved for their support and guidance.

I am extremely grateful to The Royal Welsh Agricultural Society and McDonald's Restaurants for sponsoring my Nuffield Farming Scholarship. Without this generous sponsorship this amazing opportunity wouldn't have been possible.

My sincere gratitude to my employer Wynnstay Group, and a special thank you to Gareth Davies and Dr Huw McConochie for their support and encouragement to complete my travels and my report, whilst working.

A special thank you to all those Nuffield Farming Scholars who inspired and supported me in pursuing a Nuffield Farming Scholarship, especially Rees Roberts for his encouragement and support from application to completion.

Thank you to my Nuffield Farming mentor, Jamie McCoy, for all her help and support especially through the report writing!

I would like to take this opportunity again to thank everyone I visited and interviewed, and to the people who hosted me to during my Nuffield Farming experience. Although I can't name everyone your time and generosity were outstanding and I'm extremely grateful.

And lastly I must thank all my family and my partner Gwen for their support and encouragement to pursue my ambitions of completing a Nuffield Farming Scholarship, and being away from the farm for so long!

Diolch yn fawr i chi gyd.

Iwan

19.0. References

Biswajit Roy, B. Brahma, S. Ghosh, P.K. Pankaj and G. Mandal, 2011. *Evaluation of Milk Urea Concentration as Useful Indicator for Dairy Herd Management: A Review*. Asian Journal of Animal and Veterinary Advances, 6: 1-19.

CF Fertiliser, 2015. *Sulphur grass growth booklet.* Online http://www.cffertilisers.co.uk/media/1236/sulphur_grass_growth_booklet.pdf (Accessed 29 July 2018)

Dewhurst, R.J., Mitton, A.M., Offer, N.W., Thomas, C. (1996). Effects of the composition of grass silages on milk production and nitrogen utilisation by dairy cows. Animal Science 62: 25-34.

Firkins, J L. (1996). Maximizing microbial protein synthesis in the rumen. Journal of Nutrition 126: 1347- 1354

Foskolos, A. and Moorby, J. M. 2018. *Evaluating lifetime nitrogen use efficiency of dairy cattle: A modelling approach*. Online. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0201638 (Accessed 2nd August 2018)

Gerber, P.J.; Steinfield, H.; Henderson, B.; Mottet, A.; Opio, C.; Dijkman, J.; Falcucci, A.; Tempio, G. *Tackling. Climate Change through Livestock—A Global Assessment of Emissions and Mitigation Opportunities*; FAO: Rome, Italy, 2013, ISBN 925107920X.

Google Dictionary. *Definition of Sustainability.* Online. https://www.google.co.uk/search?q=definition+of+sustainability&oq=definition+of+sustainability&aqs=chrome..69i57j0l5.6496j1j7&sourceid=chrome&ie=UTF-8 (Accessed 25th July 2018)

Prendergast.S., 2014. *A comparison of microbial protein supply of steers grazing ad libitum ryegrass or fodder beet.* Lincoln University Digital Dissertation.

Rajala-Schults. PJ.,et al. 2001. *Association between milk urea nitrogen and fertility in Ohio dairy cows.* Journal of Dairy Science. 2001 Feb 84 (2); 482-9.

Saldias.,B. 2014. *The impact of rumen function on neutral detergent fibre degradation across the diurnal period in grazing dairy cows in a pasture-based system.* Lincoln University Thesis. Online https://researcharchive.lincoln.ac.nz/handle/10182/6687 (accessed 25/06/2018).

US EPA, O. (2017) '*Overview of Greenhouse Gases'.* Available at: https://www.epa.gov/ghgemissions/overview-greenhouse-gases#nitrous-oxide (Accessed:18/12/17)

Van Amburgh, Mike. The author would particularly like to acknowledge the kindness of **Mike Van Amburgh of Cornell University** who gave him permission to reproduce in this report the slides shown in Table 1 and Figures 5, 6, 7, and 8, as well as many other slides which have not been reproduced here because of lack of space, but which the author uses in the various presentations he makes on the general subject of Sustainable Protein Feeding. **Michael Dineen, a Cornell PhD student working at Teagasc,** was similarly helpful and the author would like to give him special thanks as well.

978-1-912059-21-8

9 781912 059218 >

Published by Nuffield Farming Scholarships Trust
Southhill Farm, Staple Fitzpaine, Taunton, TA3 5SH
T: 01460 234012 | E: director@nuffieldscholar.org