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The practical feasibility of including lipids and nitrates in livestock diets

J.F. Flockhart, L. MacPherson, C. Adamik, J. Hyslop & J. Bell
Scotland's Rural College, Kings Buildings, West Mains Road, Edinburgh EH9 3JG
Enquiry received July 2017 for response by end October 2017

Enquirer: Keith McWhinnie,
Scottish Government, Climate Change & Agriculture

Executive Summary

Background

The Climate Change (Scotland) Act 2009 set out targets which add to international efforts to limit global temperature increase. Agriculture is one of several areas where human activity contributes to greenhouse gas (GHG) emissions, with Scotland producing 10.8 Mt emissions equivalent to carbon dioxide (CO_2e) in 2015. Nearly half of these emissions were from methane (CH_4), with most of this portion coming from enteric fermentation of ruminant livestock. This has been described in more detail in the rapid evidence assessment report by Rooke et al, in 2016. That work considered the nutritional strategies that could be implemented to reduce enteric methane emissions from Scottish agricultural livestock. It identified three main strategies that were considered to be practically feasible: the use of lipid, nitrate or 3-nitro-oxypropanol (3NOP).

The current project remit was to take the strategies of lipid and nitrate and examine the practicalities/limits to use that were foreseen for beef and dairy systems, including methods of feeding animals in different scenarios. To this end, we consulted experts from the supply industries that deal with these products , as well as in-house specialists in beef, dairy and commodity markets from SRUC.

Key findings

- Lipids in the form of oil or contained in some by-products of oilseed or distillery industries can be used by farmers without needing additional equipment, technology or training
- Feed oils and oily feed stuffs are widely available and require no additional legislation
- It is likely that Lipid already is (or may be) being fed at or close to its upper limit because of physical and protein constraints when feeding distillery by-products, due to their relatively high protein content
- Using nitrate compounds as a strategy to reduce methane emissions from farmed livestock by nutritional means would need strict guidelines and possibly training in its use, whatever its physical form (e.g. as an ingredient in a premix, as an encapsulated inclusion in feed blocks or as a slow-release rumen bolus)

No Nitrate compound has yet been registered in the UK as a feed additive and this unlikely in the next 3 to 5 years, as up until now there has not been a market demand for such a product, although there is precedent for using chemical nitrates such as Calcium nitrate in feed blocks in Australia, associated with a government incentive of carbon credits for farmers, introduced in 2015

Discussion

Our view is that additional farm infrastructure, technology and skills would not be necessary for the most part, if measures to encourage more beef and dairy farmers to use or increase the use of oily feeds were to be introduced. Similarly, until such time as a feed additive consisting of a nitrate compound is developed, there are already the means and knowledge on farm to be able to feed it, whether as a premix, a feed block or a slow-release capsule or bolus. This is because other additive ingredients are commonly fed in these forms, particularly premixes or feed blocks and many farmers will also be familiar with using rumen boluses to administer for example copper or cobalt. Experimental work on feeding such a product, at SRUC, has used calcium nitrate as the compound.

The market reaction to a potential upturn in demand for lipids is likely to be favourable, as there is an established market for lipid and oily feeds. As mentioned above, because oil -containing feeds are already widely used, and given that there is a natural threshold of protein and lipid content in beef and dairy rations, an increase in demand is unlikely to be acute. Current market availability of cereal distillers dark grains comes from a broader platform than solely distilleries, nowadays including biofuel by-product as well. Oil seed by-products are widely available, including some interesting, but at present smaller scale, developments in high-oil rapeseed meal in Scotland. Sheep are fed distillery by-products to a lesser extent than cattle, but are consumers of oilseed by-products, by way of compound concentrates or coarse blends containing this type of ingredient. Less evidence has been gathered about the effects of feeding methane-reducing feed ingredients to sheep than for cattle.

Contents

List of abbreviations

3NOP – 3-nitro-oxypropanol

CH_4 – methane

CO_2e – carbon dioxide equivalent

CP – crude protein

DDGS – distillers dark grains with solubles

DM – dry matter

DMI – dry matter intake

DUP – digestible undegradable protein

EU – European Union

GHG – greenhouse gases

MetHb – met-haemoglobin

N - nitrogen

NPN – non-protein nitrogen

PUFA – polyunsaturated fatty acids

NEOS – Norvite Expeller Oil Seeds (trade name)

Acknowledgements

The authors wish to thank those members of the UK Feed Industry from whom advice and expert opinion were received: John Newbold, Volac International Ltd.; Adrian Packington, DSM Nutritional Products and David McLelland, Norvite Animal Nutrition Co.

Introduction and background

Fibre-rich diets for ruminant animals promote methane production. In Scotland the majority of dairy rations and many beef systems are forage-based and therefore predisposed to generate enteric production of methane. As Scotland has pledged to reduce its GHG emissions, strategies for livestock agriculture must be considered, planned and implemented, as part of the national effort towards controlling climate change.

Ruminant animals produce methane in the two-stage process illustrated in Figure 1, below.

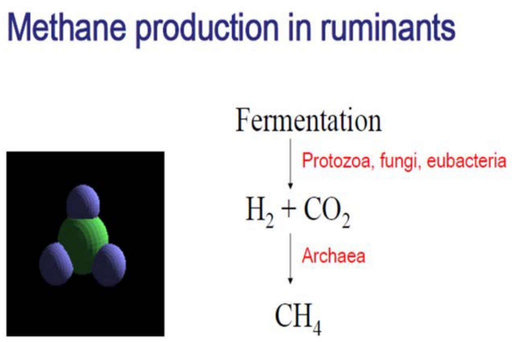

Figure 1. Process of CH_4 production

Methane is formed as part of the natural mechanism to limit the build up of hydrogen in the rumen. Without this step, the rumen micro-organism population would not be able to ferment feeds and thus provide the animal with much of its energy supply. Continuing to 'use up' the hydrogen produced in the first stage of fermentation is necessary in any feeding strategy that aims to reduce methane emissions. There are several ways that can achieve this goal; the two principle strategies examined in this report are those of feeding lipid or nitrate.

An added advantage from reducing energy lost to the animal as methane is that it could be measured in additional milk production or improved feed conversion efficiency.

Methodology

Expert opinion was sought from the feed supply industry and from beef and dairy consultants. A semi-structured interview process was used with the industry contacts. The questions posed by the project specification formed the basis of the remit to consultants.

Results

Table 1. Key risks, opportunities and consequences of using nutritional CH4 mitigation strategies

Strategy	Method	Risks to farmer	New skills or technology required?	Risks to farm business of cost or welfare	Market availability
Lipid	Protected fat	Keep to <70g/kg diet DM to avoid performance reductions	No	Global prices fluctuate	Widely available
Lipid	Whole oilseed		No	Global prices fluctuate	Available but not commonly used in farm rations
Lipid	By-product		No	Cereal dark grains co-products now being produced by bioethanol plants as well as by distilleries	Dark grains co-products available from both distillery and biofuel sources. High-oil rapeseed meal available on a relatively small scale
Nitrate compound eg Calcium nitrate	Nitrate compound in a feed additive	Risk of toxic reaction (anoxia) if overfed/ tolerance not built up, likely to lead to low/ no uptake	Would need strict guidelines, or to be applied as slow-release bolus, along with incentive scheme, credits or payment	Possible training in bolus administration, resistance from farmers predicted. Slow- release or low dose in feed blocks, no training required.	Not yet manufactured as a feed additive, cannot be sold until registered as an additive with appropriate dossier of evidence. This would apply to premixes, feed blocks and boluses.

Application of Lipid

Practical management of application: As co-products of oil production (Rapeseed, sunflower, linseed, palm) or of distillery cereal use (dark grains plus solubles of wheat, barley and maize, commonly abbreviated to DDGS). As rumen-protected form of fat eg calcium soap, or non-protected oil. Oilseed co-products and DDGS are familiar feeds, with a long history of use in Scotland due to the distillery industry. Indoor feed systems are adapted for these feeds, either mixed in a total mixed ration ration (TMR) or incorporated in compound feed pellets and meals to be fed through the milking parlour, in out of parlour feeders or in feeding troughs. Farmers are accustomed to handling and feeding such feedstuffs. Farms therefore should have appropriate storage, in a covered building, feed bin or silo. They will also have the means of delivering these feeds to indoor animals, by use of a tractor and front loader, sometimes in combination with a feed mixer wagon. Our view is that additional farm infrastructure, technology and skills would not be necessary for the most part.

Potential risks to farm business: Oilseed co-products and DDGS are commonly available and fed. Fats, including rumen-protectd fats, are expensive and there is a physical limit of how much can be fed to each animal. Higher levels of dietary inclusion of polyunsaturated fat (PUFA), especially when fed alongside high levels of rapidly fermented carbohydrate, can lead to serious milk fat depression. An important welfare note for sheep is that, because most sheep breeds are very susceptible to copper poisoning, they can be fed little or no DDGS. This is because, in many distilleries, the apparatus is made out of copper and some transfers to the co-product. Cattle can tolerate much higher concentrations of copper. The level of feeding is related to both the lipid and the protein content of these feeds. In practice, amounts of between 2 and 4kg/head/day for adult cattle are recommended and we do not foresee that this would increase in a scenario of incentive to feed more lipid-containing feeds.

Potential market reaction, perception of risk and opportunity: Level of feeding is related to both the lipid and the protein content. Excess dietary lipid has adverse effects on rumen fibre digestion, feed intake and potentially animal performance. Inclusion of lipid (straight or in co-product) should not exceed 70 g/kg DM. If a dairy cow is eating 20kg DM, no more than 1.4 kg lipid in total should be in that 20 kg. A related implication for welfare is that, as these co-products have a high crude protein content, their inclusion may be more likely to be limited to avoid excess dietary protein.

Risk of 'emission swapping': Feeding oil reduces methane production in the rumen by rendering the rumen micro-organisms less able to ferment the cellulose and starch sources from the animal feed. If the oil contains unsaturated fatty acids, hydrogen in the rumen is used in biohydrogenation which reduces the amount available for methane production. There are also likely to be changes in excreta composition.

Market availability: With the increase of anaerobic digestion (AD) plants to generate energy from straight cereal, or from distillery spent cereal, there may be less locally produced cereal by products from Scottish distilleries on the market over time. Several Scottish distilleries have now built, and are using, AD plants. Attention has been drawn to this practice and its consequences recently in the farming press (Feed Navigator, 2017), leading to increased dialogue between farming and whisky sector representatives seeking ways to maintain feed supplies. However, wheat cereal is also grown for bioethanol plants (such as Vivergo biorefinery in Yorkshire, or 'Ensus' in Teeside), resulting in a wheat dark grains co-product very similar to the traditional DDGS, including its oil content of around 7% of the DM. As a result, there is expected to have been an increase in total DDGS availability for the UK as a whole. Usage of distillery by-products in Great Britain as a whole appears relatively stable in recent years at around 400,000t per year suggesting availability has not been constrained. There are no regional figures available for use in Scotland to identify local trends.

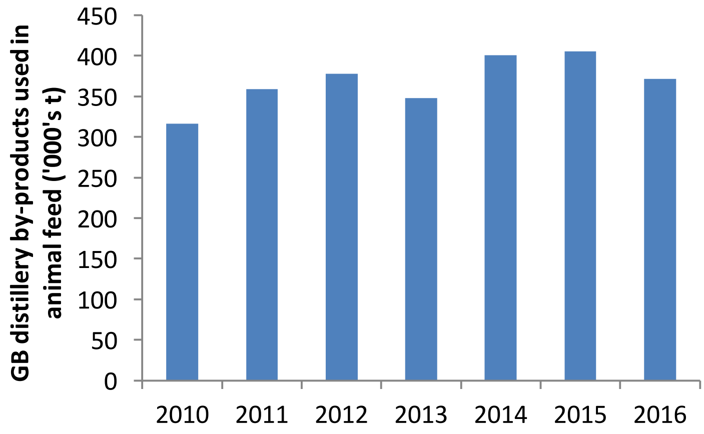

Figure 2. Distillery by-products use in GB animal feeds

Source: DEFRA, Raw Materials Usage And Production Of Animal Feedingstuff In Great Britain

There are also a number of new malt distilleries planned in Scotland with the potential for increasing total by-product output. Therefore, Scottish farmers are expected to be able to continue to access adequate quantities of distillery feed products either locally or UK produced. It is possible that there may be some price impacts particularly for unprocessed products such as draff which suffers high transport costs due to their high moisture content. However, for dried and processed products such as DDGS, any price impacts are likely to be less significant as transport costs per unit of dry matter are lower allowing product to be brought in at lower cost. Also, protein prices are driven mainly by wider global trends in the larger soya meal and rapeseed meal markets.

The global warming potential of different distillery by-products has been the subject of recent research (Ricardo Energy & Environment, 2017). This compared the impact of using distillery by-products for renewable energy, including them in animal feeds or using as a concentrated feed source. The report concluded that all of the scenarios had the potential to offset greenhouse gas emissions, with the renewable energy scenario being the most effective.

Successful implementation elsewhere: The Carbon Credits method in Australia (under their Carbon Credit (Carbon Farming Initiative) Act 2011), allows dairy farmers to use eligible feeds to add lipid to the cows' ration to reduce methane emissions. The high-oil eligible feed list includes rapeseed meal, cold-pressed rapeseed meal, brewers grains, hominy meal or dried distillers grains (Australian Government Clean Energy Regulator 2017). Research work in this area is being carried out at the University of New England, Armidale, Australia.

Application of Nitrate

Practical management of application: Most opinion and experience was that the application of nitrate to ruminants would either be as an inclusion in a premix, or as a slow-release rumen bolus (a capsule, made of a soluble material, containing an element or compound which is slowly released into the rumen The bolus is administered to the animal using a bolus gun, in a similar method to dosing animals with medicines). No new technology or training would be required to allow for the product to be administered in either of these ways.

Potential risks to farm business: The first risk of feeding nitrate salt is that animals are not given time to adjust, or are fed too much (not following guidelines on farm). The previously documented consequence of anoxia due to raised levels of met-haemoglobin (MetHb), nitrite poisoning would occur. It would need to be sold with careful control over its use and understanding of the risks. Whilst nitrate feeding has some advantages in terms of reducing methane, in two recent trials at SRUC its use was less financially attractive (Duthie et al, 2015; Duthie et al, 2017). In addition, to avoid the potential downside in terms of animal toxicity, careful diet preparation and an appropriate adaptation period have to be implemented.

Potential market reaction, perception of risk and opportunity: Calcium nitrate, as yet, is not registered in the Feed Register. In experimental work with calcium nitrate it was sourced from a horticultural fertiliser company. Debate continues as to what category of feed would be the most appropriate to register the chemical – perhaps as a feed additive or even as a zootechnical additive

Farmer perceptions on feeding specific additives to reduce methane emission have not been discussed in much detail. From the farmer's point of view the key concerns/questions are:

- Is this going to cost me extra?
- What effect will it have on performance? Positive or negative?
- Will I be compensated for this?
- Is it compulsory? If it is not compulsory, there has to be an incentive to feed these additives which would most likely have to be covered by either the milk buyer or government through an increase in milk price. This will be crucial to the farmer if the feed additive does not give a performance/financial benefit.

Risk of 'emission swapping': Feeding nitrate has the effect of changing the pathway of hydrogen to ammonia (and sometimes nitrous oxide) rather than methane. There may also be a small loss in urinary nitrate.

Market availability: Nitrate products as feed additives or as slow-release rumen boluses are not available. A manufacturer of such products would need to register them as a feed additive, either as a non-protein nitrogen (NPN) source, or potentially as a zootechnical additive under a new purpose of methane mitigation. Calcium nitrate has been used in experimental work because there is no explosion risk unlike other nitrates (ammonium nitrate or potassium nitrate, for example).

Successful implementation elsewhere: There is most evidence of this from Australia, less from USA, possibly as central funding for climate change mitigation has been less strongly pursued in USA. Australia has experience of feeding nitrate salt to beef cattle in particular, through the method approved in 2014. Beef farmers are encouraged to replace urea with nitrate supplements in grazing animals, by a system of credit points (Meat and Livestock Australia, 2015). The figure quoted by the Australian Govt. Dept of Agriculture is that feeding nitrate salt at 10g/kg of DMI can reduce methane emission by 10%.

Brazil is developing a slow-release form of nitrate. In trials, when pulse-dosing the slow-release nitrate and pure nitrate and then measuring met-haemoglobin over time in bulls, researchers measured about a 50% reduction on MetHb level compared with pure nitrate. In Scotland, as our forages contain plenty of Nitrogen (N) or non-protein nitrogen (NPN) we would not normally replace urea in practice, which is different from Australia or Brazil.

Discussion

We think that additional farm infrastructure, technology and skills would not be necessary for the most part, if measures to encourage more beef and dairy farmers to use or increase the use of oily feeds were to be introduced. The majority of farms will have storage facilities and equipment to be able to use such feeds. When considering the scenario of feeding a nitrate compound contained in a feed, many farmers will be familiar with handling feed additive premixes or feedblocks, and may also be familiar with using rumen boluses to administer for example copper or cobalt. However, there is not the experience of feeding a product whose dose needs to be controlled very carefully to avoid toxic effects and this would need to be overcome through a system of training and carefully-followed guidelines if it were to succeed. Some forms of nitrate salts, for example ammonium nitrate or potassium nitrate, would not be able to enter any list of feed additives because of the risk of explosion; only a non-explosive form such as calcium nitrate would possibly be considered.

The market reaction to a potential upturn in demand for lipids is likely to be favourable, as there is an established market for lipid and oily feeds. As mentioned above, because high-oil feeds are already widely used, and there is a natural threshold of protein and lipid content in beef and dairy rations, an increase in demand would not be likely to be acute. Market availability of cereal distillers dark grains comes from a broader platform than solely distilleries, nowadays including biofuel by-product as well. Oil seed by-products are widely available, including some interesting but at present smaller scale developments in high-oil rapeseed meal in Scotland. Although sheep would not normally be fed distillery by-product due to the risk of high copper content, the options of oil-seed by-products and low-copper biofuel by-product are alternatives.

Policy implications

If a feeding policy, for example a minimum content of oil in beef and dairy rations, were to be mandatory, a compensation or credit system should be considered.

Such an approach would work best if it was run together with other known methods to reduce methane emissions. These are optimising the productive life of dairy animals, reducing the time for beef animals to reach slaughter weights and using high-concentrate beef rations or high-quality forage plus concentrates for milking animals.

Conclusions and Recommendations

- Lipids in the form of oil or oily by-product of oilseed or distillery industries can be used by farmers without needing additional equipment, technology or training
- As feed oils and oily feed stuffs are widely available and require no additional legislation for their use, it would be relatively easy to encourage their use
- Lipid may already be fed at or close to its upper limit because of physical and protein constraints
- Using a nitrate compound as a strategy would need strict guidelines for farmers and training in its use, whatever physical form it took
- No nitrate compound has yet been registered as a feed additive and they may not be used as such at present
- There is precedent for using nitrate in feed blocks in Australia, associated with a government incentive of carbon credits. This means of incentive could be considered as a potential model for Scottish farmers

- Incentive through pricing schemes for milk or carcases could work if milk or weight gain as a result of reduced methane production can be reliably measured

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Annex 1. Dairy and Beef feeding systems in Scotland

Beef: The beef sector has accounted for 22% of Scottish agricultural output over the last 10 years and is the largest sector in Scottish Agriculture (Scottish Govt. 2017). The number of beef animals in Scotland has remained at 437,000 head between 2015 and 2016 and price for beef in 2016 had improved from 2015 (AHDB yearbook 2017 (Cattle))

Nowadays, most producers are choosing a semi-intensive system, whereby spring-born beef calves are suckled on their dam, with some additional creep feed. Between August and October of their first year they are weaned and are fed indoors as store calves for their first winter. They have a grazing season as a one-year-old animal before being brought in to be more intensively fed indoors, from about July-August for 3 to 4 months, thus meeting the Christmas market at about 20 months of age. This is well within the 30 month rule, which itself encouraged producers to choose an early maturing animal. Carcase weights of 400kg are common, having dropped from around 450kg. Grazing for longer (ie a second grazing season post-weaning) makes a larger carcase and is less efficient in terms of feed conversion efficiency (FCE).

Dairy: Dairy farming systems and hence feeding systems are very diverse in Scotland. Feeding systems vary with breed, milk yield, calving pattern (year round or block), time of year, geographical area, infrastructure and land type/grazing conditions.
There were 175,000 head of dairy cattle in Scotland in 2016, similar to 2015, from 1832 holdings (Defra, 2016), with an average herd size of 96. The main management systems include traditional grazing with no forage fed indoors in summer (31%), some summer indoor feeding of forage (38%), continuously housed (8%) and purely outdoor (1%). The most typical are composite systems, lying somewhere between low-iput pastoral and high-input purchased feed approaches (March et al, 2014).

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Annex 2. Strategies for dairy – SRUC expert opinion

Dr Lorna MacPherson and Dr Csaba Adamik, SAC Consulting Ltd

The type of feeding system may affect the practicalities and accuracy of feeding additives to reduce methane emissions. Various feeding systems for providing concentrate feed and the practicality of delivering methane reducing feed additives are summarised below:

- Simple feeding systems providing forage and parlour feed. Cows are either fed silage in the winter and/or grazed during the summer months and are fed a compound feed (cake) through the parlour, usually at a rate according to milk yield. This system would make it difficult to incorporate feed additives. If an additive was included in the parlour feed, an accurate feeding level cannot be achieved as parlour cake can be fed between 2 to 8kg/cow/day depending on milk yield. However, the option exists for feed additives to be included in parlour cakes in those situations where parlour feed is fed flat rate for all cows in the milking herd (i.e. 4kg parlour cake/day). In this situation if further quantities of concentrate were required, it is usually delivered either through a partial mixed ration (PMR) or through out of parlour feeders. These systems could use a feed additive to be fed at a set daily rate and the feed additive could be incorporated into the daily portion of parlour feed received by all cows in the milking herd.
- Parlour feeding is also employed in medium to high yielding herds but the same problem exists in terms of accurate feeding of additives as most farmers will feed to yield in the parlour.
- Out of parlour feeders – individual feeding stations where cows receive a concentrate feed (again normally based on level of milk production). Out of parlour feeding systems exist in herds both with and without parlour feeding. Again, they would not provide accurate intakes of feed additives.
- Complete total mixed ration (TMR) – this is where the cow receives all the daily feed allocation from a ration where forages, concentrates, minerals and feed additives are mixed together in a mobile feeder/mixer wagon and available *ad lib* throughout the day. This feeding system enables a fairly accurate way of feeding the correct level of feeds to each cow (note feed intake will however vary with stage of lactation as well as feeding space).
- Herds with robotic milking – cows are milked in robotic milking units placed in the area where cows are housed. Cows receive part of their concentrate allocation through the feeding system installed in the robotic milking units.
  Issues with this system are very similar to those with parlour feeding and out of parlour feeding: the quantity of cake consumed is varied for each cow – it doesn't provide an accurate way for feeding low inclusion feed additives through the cake.
  However some of these systems are equipped with units where either liquid or powdered feed additives can be dosed on the cake consumed while the cow is being milked. These would be a possible option to feed low inclusion methane reducing feed additives.

- In the summer time, some herds will graze cows at grass and during this time it is common practice to also provide a buffer feed (containing forages/concentrates and other feed additives as required). This would provide a method to feed methane reducing additives fairly accurately if required). Very high yielding herds are more commonly housed through the summer months and fed a total mixed ration.
- Not all dairy farms have a mixer wagon to enable accurate feeding of low inclusion feed additives. The lack of feeder wagon perhaps would be more typical of lower yielding herds that graze in the summer.

- Free access molassed mineral buckets or powdered minerals are a way in which potential CH_4-reducing feed additives could be included for dairy cows. These products are commonly provided when cows are grazing to ensure adequate mineral intake (if buffer feeding is not practised or concentrate intake is limited in low yielding herds receiving parlour cake only). However, intakes are extremely variable when these supplements are offered in this way and this would not be an accurate method of delivering such additives (especially Nitrate products, where overdosing may be a risk to health).

The type of feeding system can vary greatly across Scotland. In the west of the country where there is more grass growth (and perhaps poorer land/climate for growing cereals), dairy farms will be more likely to graze their cows. In the very far west of the country, where there is a longer grazing season, spring calving is more common and more "New Zealand" type grazing systems - that is, where cows are grazed for as long a season as possible in order to maximise the amount of milk produced from grass alone - are adopted (for example, around Stranraer). These systems may make the feeding of nitrate additives more challenging, depending on milk yield and what other feeds are being fed and how they are fed. Farms that feed with a mixer wagon will be more able to incorporate feeding additives accurately into the diets of milking cows, especially during the housed winter months. Feeding of these additives in the summer may be more of a challenge depending on the feeding system.

Annex 3. Strategies for beef – SRUC expert opinion

Dr Jimmy Hyslop, Beef Specialist and Julian Bell, Senior rural Business Consultant, SAC Consulting Ltd

Q1. How would livestock farmers in Scotland manage the application of lipids and nitrates? Would additional technology and skills training be needed?

Use of high lipid containing diets for ruminant livestock in Scotland should be relatively easy and widely accepted given that such feeds and therefore diets are fairly commonplace at the moment. Certainly, high oil containing distillery co-product feeds have been widely used in Scotland for many years and farmers are very familiar with them. The recently introduced Norvite Expeller Oil Seeds (NEOS) products containing up to 150 g/kg oil in their dry matter (DM) should also be accepted with little or no problems provided that proper guidance is available from the company marketing them. Norvite already seem to have the basics of this in hand although any developments involving the use of these products that farmers are not familiar with will need support with the appropriate advice and underpinning science. When it comes to feeds with added oil components which could be marketed as an aid to improving efficiency and reducing methane, then it should be emphasised that these products can be used effectively as long as the overall oil content of the ruminant animal's whole ration does not exceed 60 g/kg DM. Little or no additional technology or skills training should be necessary assuming that existing relatively high-lipid containing feeds are used.

The situation would be somewhat different if high nitrate feeds were to be developed for use in ruminant diets as an aid to reducing methane emissions. There is considerable risk of animal toxicity where nitrates are fed if animals are not introduced to the product gradually and receive it on a little and often basis. Rapid introduction or large doses of nitrate can lead to nitrate poisoning with high met-heamoglogin (met-Hb) levels in blood being seen in some critically sensitive animals. In extreme circumstances this may lead to severe ill-health or even death in some animals. Consequently, if such products were to be developed for use by practical farmers one of two strategies would be advisable. Either these nitrate products should be developed using "slow release" technology so as to avoid animals receiving large doses (e.g. slow release nitrates incorporated into feed blocks for outdoor feeding). Alternatively, where nitrate containing feeds are incorporated into typical indoor diets then a widespread KE programme would be needed to provide appropriate feeding and management advice to farmers using these feeds so that potential problems with nitrate toxicity are avoided.

Q2. What is the evidence for potential risks to the farm business, in terms of costs (including time and finance) and animal welfare?

A major study at SRUC in recent years (Roehe et al, 2015) examined the use of both lipids and nitrate ingredients in beef cattle finishing rations and concluded the following:-

1) The effects of Nitrate or Lipid on methane production depended on the basal diet fed. On the Mixed diet, Nitrate reduced methane emissions by 17% and Lipid by 7.5%. On the Concentrate diet, neither Nitrate nor Lipid reduced methane emissions. There was no breed effect on methane emissions. Use of the concentrate basal diet reduced methane emissions by 33-41% compared to use of the forage:concentrate basal diet (50:50 on a DM basis).

2) Following an appropriate adaptation period (four weeks), feeding Nitrate (18 g nitrate/kg diet DM) with either the Concentrate or Mixed basal diets did not provide measurable adverse effects on animal health.

3) Using rapeseed cake to increase dietary Lipid from 27 to 51 g /kg diet DM did not suppress feed intake or reduce live-weight gain, suggesting that diets containing 50 g / kg diet DM or less lipid have no adverse effects on animal performance.

4) Using maize distillers dark grains to increase dietary Lipid from 25 to 37 g /kg diet DM did not suppress feed intake or reduce live-weight gain, confirming the Evaluation study results that diets containing 5% or less lipid have no adverse effects on animal performance.

5) During a 56 day performance test, neither Nitrate nor Lipid adversely affected animal performance. Carcass quality traits were not influenced by either Nitrate or Lipid.

6) Whilst Nitrate feeding has some advantages in terms of reducing methane, in both trials studied here its use was less financially attractive. In addition, to avoid the potential downside in terms of animal toxicity, a careful diet preparation and an appropriate adaptation period has to be considered. Consequently, Nitrate feeding cannot be recommended to practical farmers at this stage.

7) Feeding high Lipid feedstuffs in finishing cattle diets can be recommended provided its use is economically competitive and excessive lipid levels in the total diet above 60 g/kg DM are avoided.

8) The above conclusions are made in the absence of financial incentives to reduce methane emissions. If this situation changes, then these recommendations can be reviewed at any time.

To put these conclusions in context it should be stressed that reducing the time it takes to produce a finished carcass (i.e. reducing days to slaughter) and use of traditional high concentrate diets are clearly the most effective ways to reduce methane emissions from beef cattle finishing systems (30-40 % reductions can be achieved). In comparison, including high lipid levels or nitrates in rations reduce methane emissions by only 17% and 7% respectively. Consequently, the hierarchy of advice to beef finishers on ways to reduce methane emissions (and improve efficiency of production to improve profit) should be in the following terms:-

1) Reduce days to slaughter

2) Use concentrate feeds appropriately and efficiently to improve performance

3) Use high lipid feeds where appropriate and when they are competitively priced

4) Nitrate feeding cannot be recommended at this time due to potential toxicity problems and high cost.

Q3. What is the state of evidence of potential market reaction and is there evidence to suggest perception (both farmer and consumer) of significant risk and or opportunity?

Adverse market reaction from either farmers or consumers to the use of lipids in farm animal diets is unlikely to be an issue given that lipids are already a basic component of animal diets. This is likely to be particularly true where the use of existing high lipid containing feedstuffs is envisaged (e.g. distillery co-products or rapeseed meal derived products). However, when the potential toxicity problems of using nitrates in ruminant diets are explained to farmers (and consumers) then there is likely to be some resistance to their use, especially when there is only a poor opportunity for economic advantage and minimal reductions in methane output as a result.

Q4. What is the state of the market availability of lipids and nitrates for Scottish farmers – what are their risks and opportunities?

Lipids are primarily available to farmers as constituents of freely available animal feedstuffs. Almost all feedstuffs of both concentrate or forage origin will contain lipids or oils to some extent (10-40 g/kg DM) however higher levels of lipids (40-150 g/kg DM) are generally found in a few distinct feeds of concentrate origin. In Scotland, many of the co-product feeds produced by the distilling (and to a lesser extent the brewing) industries do contain significant levels of lipids as a result of their industrial processing designed to extract starch from the base cereals. This has the effect of concentrating the lipid, protein and fibre fractions of the base cereals in the remaining co-product feed (wet distillers grains [draff], brewers grains, along with the three major types of dried distillers "dark" grains – barley, wheat and maize dark grains) can all contain 60-150 g/kg DM of lipid or oil. Maize Dark Grains can be particularly high in lipid, typically 100-150 g/kg DM reflecting the oil content of the original cereal grain. The availability of these distillery co-products in Scotland has traditionally varied with the cyclic nature of whisky production (the "whisky cycle"). In recent years local availability in parts of Scotland, particularly of unprocessed products such as draff, appears to have altered due to a) the increased use of distillery co-product feeds in anaerobic digestion or biomass power generation plants that have developed over the past decade and b) Cereal dark grains now being produced by bioethanol plants. Across the UK as a whole however, distillery by-product output is likely to have increased due to the expansion of wheat based ethanol production in the north of England, accessible to Scottish farmers by road transport. Figures from DEFRA (2017) show that total use of distillery by-products in animal feed across Great Britain has remained relatively high and stable in recent years. Tonnages of total available product in Scotland has been recently summarised by Bell et al, (2012) and are listed below.

Table 1. Tonnage of distillery co-product feeds available in Scotland 2012 containing appreciable amounts of lipid.

	Fresh weight (t)	Dry weight equivalent (100% DM)
Malt distillers "draff"	300,000	75,000
Grain distillers moist feeds	240,000	79,200
Barley Dark Grains	75,000	67,500
Wheat & Maize Dark Grains	110,000	99,000

Source: Bell et al, (2012). Distillery feeds by-product briefing. An AA211 special economic study for the Scottish Government.

Appreciable quantities of up to 1 million tonnes p.a. of similar dried products are now being produced from bio-ethanol distillation facilities in the north of England for use across the UK. However, they tend to contain lower levels of oil (50-80 g/kg DM) compared to much of the Scottish "distillers dark grains".

NEOS feeds (Norvite Expeller Oil Seeds) are now being produced by Norvite and are derived from the cold pressing of Scottish produced oilseed rape on an industrial scale (as opposed to small farm scale units to date). The NEOPRO product has both a high oil content (120-150 g/kg DM) and a high protein content (280-320 g/kg DM) so provides excellent nutrition for ruminant animals in particular and the oil will tend to reduce methane production when this rapemeal product is fed as part of a ruminant diet. The NEOFLO rape oil product would have similar properties with regard to methane reduction if fed to ruminants. However, at the moment its main market use is as an ingredient in pig and poultry diets so it has little impact on methane emissions. Currently, Norvite produces approximately 2000 tonnes per annum. each of both NEOPRO and NEOFLO although development of the facility is underway which should see these quantities triple in the next few years.

Nitrates are not yet widely available to farmers as an added constituent of animal feedstuffs although very small quantities of natural nitrate compounds are found in many commonly available feeds. The artificial fertiliser calcined nitrate is sold commercially by the major fertiliser company (YARA Ltd) as "Calcinit" but its only real use in animal rations to date has been as a source of nitrates in animal feeding experiments (such as those conducted at SRUC). No real market exists for added nitrates (Calcinit) as a component of animal feedstuffs to date.

Many compounded or blended feed mixes are available throughout Scotland and may also contain added levels of lipid or oil slightly above those levels that occur naturally in the original feed ingredients. These small amounts of added lipid are usually incorporated in the form of liquid oils, rarely exceed 60 g/kg DM total oil for ruminant animal feeds, and are often added as an aid to industrial processing as much as an additional source of animal nutrients.

The existing lipid or oil containing feeds used in Scotland are well accepted by the marketplace and present few risks since they are well established products. The exception to this would be the recently introduced NEOS products which may benefit from R&D activity to establish their optimum uses in various classes of Scottish livestock and their associated effects on methane production. It is difficult to see any significant market for added nitrates in the form of Calcinit or similar products developing any time soon given the additional costs to producers and the considerable toxicity risks that may occur if it is fed incorrectly.

References

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Roehe, R. et al. (2015) Nutritional improvements using diets and novel feed additives to enhance overall efficiency of beef production including meat quality and mitigation of greenhouse gas emissions as identified by characterisation of the rumen microbial population. AHDB Beef and Lamb Final report (Project No 66714)

Annex 4. Evidence of implementation of these feeds elsewhere

Industry interview (John Newbold 10/08/17).

Provimi/Cargill (joint since 2011) had a Dutch/EU interest in the feeding of nitrates to ruminants question. At the time, some years ago, this was viewed in terms of measuring/reducing CO_2 equivalent emissions. Since then, Phosphorus has been more concerning and has occupied EU attention more, away from carbon emissions and methane.

From an international perspective, in Brazil there has been the challenge of reducing methane from their beef herd. Much of this comprises Bos indicus breeds, which are grazed on rangeland for up to 4 years before coming in for a relatively short time in a feedlot with intensive feeding of concentrates. These breeds are small and take a longer time to reach maturity relative to beef breeds that are used in Europe. The time on rangelend is when the majority of methane emissions will take place. Thoughts on application of nitrate in consumable form have been through a mineral mixture.

Reducing CO_2 equivalent in Australia and New Zealand has also been a pressing question for many years, perhaps rather less so more recently with governments for whom climate is not quite so high up the priority list. These are places where a high proportion of their greenhouse gas emissions are from agriculture. Looking at nitrates in the Australian context was through the idea of using feeding blocks, containing slow-release encapsulated nitrate. This was to control the level of intakes to a safe amount. Work examining whether a period of adaptation to feeding with nitrate compound is helpful or not helpful in animals being susceptible to nitrite poisoning has not led to a clear answer but remains equivocal. The major issue is the risk of elevating levels of methaemoglobin in the blood.

There has also been work to define which rumen bacteria species are responsible for the stages of nitrate breakdown – to nitrite, and nitrite to ammonia, and so on.

Literature in this area – work by Roger Hegarty, preceded by John Nolan (University of New England, Armidale, Australia).

In the UK and Scotland in particular, nitrate could be classed as a non-protein nitrogen source, or as a calcium source, but this would be disingenuous as we know it is being used for a defined purpose. It could possibly be classed as a feed additive – for which supporting documentation on safety and efficacy would be required, or as a zootechnical additive with particular function, the new purpose of methane mitigation.

Also consider that some forms of nitrate can be explosive, others are safer and can be transported and used with less risk.

Implications in the food chain

If the animal is consuming even low, safe, levels of nitrate, it is likely that some molecules will come through into the food product for which it is being farmed – meat or milk - and this in turn poses a consideration for human health. There has been work on the harmful effects of Nitrosamenes (carcinogens) in processed meat (eg smoked or cured), derived from nitrates used in the preserving process. These have been known about for many years, and to put it in context, smoked and cured meat products are widely available foods and within current guidelines. The question arises – if the meat or milk has slightly higher levels of nitrate (from feeding to reduce methane emissions), even if only slightly elevated, how much will this influence the levels of nitrosamenes in that product if cured/smoked?

However, there are also positives in the nitrates story!

Take beetroot juice – promoted as a health food amongst athletes. Because beetroot is naturally high in nitrates, this can improve energetic efficiency, through enhancing cardiac function, thus stimulating performance. Studies from Sweden demonstrate that low levels of nitrate in the human diet can enhance mitochondrial activity.

In the UK/EU, the AnimalChange project was a multi-partner initiative including Provimi/Cargill, INRA and Aberystwyth University among others; this looked at nitrate in dairy diets as well as feeding lipid such as linseed oil. A companion experiment was run in NZ through AgResearch.

There is still a feeling that the gap between a nitrate dose to get a meaningful response in lowering methane emissions in a cow and the amount that is toxic is too fine to make it an attractive proposition for farmers, advisers or policy makers.

Interview with David McLelland of Norvite, 15/8/17

Neopro high lipid rapeseed expeller product made by this company. Envisaged for feeding in TMR to cattle, beef and dairy.

A Scottish high-oil preparation of rapeseed meal (traded as Neopro by Norvite Ltd, Aberdeenshire) contains 12% oil and 30% crude protein on an as-fed basis. Can be used as a straight feed or in blends. Current work suggests that the DUP fraction (digestible, undegradable protein, that is, cannot be degraded by the microbial activity in the rumen but can be digested further down the digestive process by acid and enzyme activity) can be treated to make it more rumen-protected. In dairy cows, it can alter the fatty acid composition of milk.

Palm fatty acid distillate and palm derived products are less and less acceptable and not wanted by supermarkets.

Rapeseed oil and meal can be locally sourced so is a good story for Scotland.

There is a Farm Advisers Register (FAR), a professionally accredited body for which continuing professional development (CPD) updates can be earned. There is an environmental module, including, for instance, awareness of nitrate vulnerable zones. It is estimated that feed company sales advisers make 20,000 calls onto UK farms each day, which is a very effective way to spread knowledge about environment and get feedback.

Neopro production is approximately 8,000 to 12,000T a year, so there is scope for other products, as this will not be enough to feed to all beef and dairy animals in Scotland. Distillery co-products of dark grains and solubles (DDGS) have had a long history of being used as valuable animal feeds, and they also contain oil (highest is maize DDGS).

Interview with Adrian Packington, DSM on 28/8/17

Following information about 3-nitro-oxypropanol in the 2016 report, the dose rate work has been completed by the company and the (manufactured) molecule patented. Toxicology work has also now been completed. There needs to be an economic justification for using, how will the energy partitioning work (if methane not being produced) in beef and dairy cattle? Making the case to EFSA will probably be time consuming, even with complete toxicology report. Also, industrialisation for manufacture of this product has not started, with no guidance as to the size of factory or what output would be per annum. The company do not know market demand at all yet. This may be a product not driven by market pull but by government push.

Early work on this molecule at CEDAR (C. Reynolds) discovered that 3-nitro-oxypropanol, like other rumen modifiers, has to be fed continuously to have a consistent effect – hence the idea of slow-release either in a bolus or in a premix. Stephan Duval and Jamie Newbold were the principal investigators at Rowett and Aberystwyth, respectively.

It has been established that an inhibition level of 30% of methane is realistic/achievable, although if the highest dose is given 60% inhibition would be possible.