The complexities of reducing on-farm greenhouse gas emissions – making farming even more efficient

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- Reducing the C footprint of agriculture is imperative but also highly complex, with reductions in one area often causing a rise in another.
- A reduction in concentrate feed helps to cut GHG emissions and input costs but can result in lower daily gains and the animal taking longer to reach target weight resulting in increased emissions.
- Reducing days to slaughter requires the provision of high-energy feeds, the production of which can cause environmental problems and sometimes health issues for the animal.
- Such complexities must be carefully considered and balanced and a holistic strategy adopted when looking to reduce the C footprint of a farm.
- Studies suggest that selective breeding programmes with a focus on feed efficiency, good fertility and health are effective and can help to offset GHG emissions.

In the quest to reduce greenhouse gas (GHG) emissions and increase environmental sustainability the agricultural industry is being placed under increasing pressure to minimise its carbon (C) footprint. However, a vital aspect of this plan is missing, how exactly is this achieved? There are many proposed methods for reducing the C footprint of farming, the majority of which are based on simulations and lifecycle analyses (LCA) intended to emulate real life. Of course, a computer-generated representation will never fully capture the full range of variables that affect GHG emissions in real life, hence, one of the primary limitations of these studies comes to light. Nevertheless, these experiments are important, because to prove a reduction in emissions a baseline must first be established and until the technology is developed that is capable of measuring GHG emissions in real-time from land, animals, vehicles and slurry alike, a simulation is the most accurate way forward.

One such proposed method for reducing on-farm GHG emissions is to reduce “what’s going in”, *i.e.* less concentrate feeds, fewer days to slaughter and reducing calving interval. Simply put, if an animal is alive for a shorter period of time, there is less opportunity for feed consumption and the generation of emissions. Similarly, the more reproductively efficient an animal can be, the more offsets (in meat or milk) are produced over its total lifetime.

Reducing days to slaughter

Reducing the number of days to slaughter may seem like a simple and logical method for reducing GHG emissions, but on second look, the situation is more complex. Should the animal finish sooner, it will likely finish at a lower weight resulting in a low sale price and potential difficulty in finding a buyer. As such, the animal must be finished to target weight in a shorter time frame usually through providing a high quality, high concentrate diet. This is an attractive method given that scientific studies have consistently shown that concentrate-based diets result in lower methane (CH_4) emissions too. This occurs as the rumen microbiota produces more propionate and less acetate and utilising hydrogen and limiting its supply for the formation of CH_4. Of course, high concentrate diets are not without their drawbacks: ruminants are poorly adapted to digesting grains with the husk remaining in the gut which can lead to colonisation by pathogens and infection, in addition to the well-known issue of ruminal acidosis. In terms of profits, buying in concentrates is an expensive option although if the feed is homegrown this can help to reduce the environmental footprint of the business and will allow savings in the long term. When buying in concentrates there is also the issue of land-use change, pollution, deforestation and plethora of environmental issues in the country of origin, as well as GHGs produced in the export/import process. So, is this a preferable option? Do the reductions in GHG production by the animal offset the issues presented by a high concentrate diet? A key element of analysis is the boundary for consideration – if the farm gate is where the measurement of GHG emissions stops, then indeed, this strategy is promising, however, when a whole lifecycle analysis is carried out, encompassing global impacts, the method is less effective.

Where animals, sheep, in particular, are reared on upland and marginal grassland a significant proportion of diets will consist of forage which tends to produce higher levels of CH_4 than concentrates or lowland pasture (Table 1). However, these upland and hill areas have a role in CH_4 capture (albeit minimal) and their management via low-intensity grazing is important in achieving wider agri-environmental objectives and maintenance of public goods.

Kg CO_2e/kg live weight	Hill	Upland	Lowland
Average	13.6	11.0	11.1

Table 1: Average greenhouse gas (GHG) emissions given in kg of carbon dioxide equivalents (CO_2e) per kg of live weight for sheep in different systems – lowland, upland and hill, data taken from EBLEX (2013).

Over the last century, animal productivity has increased considerably, with fewer animals being needed to generate the same amount of produce which offsets GHG emissions. However, consumers still perceive extensive, non-intensive systems as more environmentally friendly. Contrary to this belief, studies suggest that pasture finished beef has a higher C footprint than those finished on a concentrate-based diet (19.2 kg vs. 14.8 kg of carbon dioxide equivalents (CO_2e)/kg). This is mostly due to faster growth rates in animals finished on concentrates which were able to achieve target weights up to 7 months earlier than those finished on grass. Research suggests that the most economically viable options are not always the most environmentally friendly ones, with slaughter at 19 months after finishing at pasture with supplementary feed providing the best returns, but finishing indoors on ad-lib concentrate producing the lowest GHG emissions. Whilst pasture-based systems produce lower carcass weights, concentrate feed costs are also significantly reduced resulting in a greater net margin. However, across the board, reducing concentrate feed increases GHG emissions. The balance between economic and environmental optimum is an important concept and one that requires careful consideration when making changes to systems to reduce GHG emissions.

In many parts of the world, particularly the USA, feedlots are frequently used to finish beef cattle on high energy, concentrate-based diets. This strategy uses a minimal amount of land at a high stocking density, which, whilst not the optimum option for animal health and welfare does produce significantly fewer GHGs compared to grass-based systems. In such systems, the feedlot only contributes around 20% of total emissions, however, feed production contributes to between 38 and 42%. In this situation, perhaps the most important offset to GHG emissions would be to increase feed efficiency and average daily gain (ADG) – traits that may be improved through the use of genomic selection and selective breeding programmes.

Reducing concentrate feed

Similarly, reducing reliance on concentrate feed may seem like a straightforward and effective approach to reducing GHG emissions. But is it that simple? When concentrate feed is cut and forage provided is not of high quality, ADG drops and animals take longer to finish, resulting in more time in which to produce GHG emissions. Target weights are not achieved which makes the carcass difficult to market or fetches a lower price. Such a paradox is known as 'pollution swapping', for example, feeding diets containing high levels of cereal may reduce enteric CH_4, but emissions associated with the production of the feeds themselves may increase overall emissions. In addition to enteric emissions as a result of feed changes, the subsequent variation in manure output should also be factored into GHG calculations. For example, the C footprint of supplementary feed has been estimated as similar to the impact at 10-11% of total emissions, but, when the N_2O emissions from manure are considered this figure jumps to 35%.

A comparison of high and low concentrate rations in dairy cattle found a trade-off between impact to biodiversity and overall C footprint. Higher concentrate diets could reduce C footprints (0.31 CO_2e/kg) but these reductions were lessened when soil carbon sequestration was considered (0.23 CO_2e/kg). As expected, biodiversity measurements were negatively affected by concentrate-based diets when compared to lower concentrate utilisation. In sheep farming, C footprints vary drastically, with one study finding a range of 0.23 - 55.08 kg CO_2e/kg product. This suggests that certain extremely efficient systems produce next to no emissions, which in turn suggests that there is room for improvement.

It is also important to consider land-use change required to produce feed; high-concentrate diets reduce enteric CH_4 emissions but is this enough to balance out GHGs released during the production of said feed? A Dutch study investigated the replacement of grass silage with maize silage as a means of reducing enteric CH_4 emissions at three different levels: animal, farm, and chain level. The study showed that the level of analysis strongly influenced results and conclusions. At the animal level, the strategy worked and reduced annual emissions by 12.8 kg CO_2e/ton of product. However, analysis at farm and chain level revealed first of all that the strategy is not always physically possible due to certain EU regulations that prohibit a reduction in grassland area. Although, for the more intensive farm that can reduce its area of grassland, annual emissions were reduced by 17.8 kg CO_2e at farm level and 20.9 kg CO_2e at chain level. Ploughing grassland into maize land, however, resulted in emissions of 913 kg CO_2e. At farm and chain levels, therefore, the strategy does not immediately reduce GHG emissions regardless of animal-level results. It was estimated that at chain level it would take 44 years before the reduction in emissions offset those from land-use change.

Overall, even when the additional land and inputs needed to produce concentrate feed are considered, intensively reared animals use less land than those in extensive systems – since feed crops are more nutrient-dense than grass, less area is needed for a given quantity of nutrition. Fewer GHGs (in particular CH_4) are also emitted. By contrast, extensively reared animals produce less edible output per unit of GHGs emitted and on a global scale are responsible for a significant amount of livestock-induced agricultural deforestation. Pigs and poultry require even less land and produce fewer emissions than ruminants, since their feed conversion efficiency is greater, and the monogastric digestive system produces next to no CH_4. Perhaps the most environmentally friendly method of rearing livestock is to use a mixed system or graze on land that cannot support crops. In a mixed system, for example, livestock might be grazed in rotation with crops and contribute manure. Moreover, if well managed, grazing livestock on pasture can contribute to the maintenance of ecosystems and biodiversity. Some research suggests that grazing systems can increase soil C sequestration – but findings are mixed and benefits are time-limited. Another mitigation strategy with regards to feed is the use of crop residues or food waste that humans cannot consume, allowing inedible waste to be converted into human-edible animal protein.

Reducing calving interval

Another method for beef and dairy industries may be to reduce calving intervals (CI) and to optimise age at first calving (AFC). Calving interval refers to the time between calvings and should be 365 days or exactly 1 year. Optimum AFC for both dairy and beef heifers is 22-26 months old, averaging at 24 months of age. Whilst maintaining optimum AFCs and CIs can be challenging in practice, doing so will optimise productivity, profitability and improve the longevity of cows, in addition to potential reductions in GHG emissions.

The past few decades have seen a steady decline in the fertility of dairy herds which may contribute to longer CI. One study found that if fertility levels were restored to those in 1995, CH_4 emissions could also be reduced by 10-11% and ammonia (NH_3)

by 9%. Inputting optimum fertility levels into the simulation resulted in a 24% reduction in CH_4 emissions and NH_3 by 17%. This work suggests that the main influencing factor on emissions is the number of replacement heifers required, whilst CI, changes in annual milk yield and diet composition have less significant effects demonstrating the importance of looking at the issue of fertility as a whole.

Using the Irish Maternal Replacement (MR) and Terminal Beef (T) cattle indices in simulations can also indicate the potential effects of genetics on GHG emissions. Use of the MR index reduced GHG emissions by 0.810 kg CO_2e/breeding cow. These reductions were driven by improvements in cow survival, reduced feed requirements, shorter calving interval and reduced offspring mortality. For CI, the analysis calculated that for each day increase in the interval an additional 1.232 kg of CO_2e/day would be produced. As expected, CI had a knock-on effect on the total number of offspring and therefore impacted the number of calves sold per cow, per year. The simulation suggested that shortening CI could increase emissions through higher feed requirements of gestating/lactating cows and a greater number of offspring produced per year but that this may be offset by meat produced from offspring, the net effect being a reduction in emissions. The model also predicted that reductions in AFC would have a positive effect on gross emissions and emissions intensity, although not as significant an effect as CI. Putting a price on this, Australian scientists found that for every day over the average CI, costs increased by $2.49 - $2.61 day/herd. This work suggests that this is a complex issue to which a compound approach is needed, with factors like CI, AFC, calf survival rate and feed efficiency forming crucial parts of a more holistic plan.

Overall, shorter calving intervals produce more calves per cow per year leading to a reduction in GHG production per unit of beef or milk. So, a tight calving interval of 12-13 months and achieving the recommended AFC of 24 months helps to create an efficient and productive system for both beef and dairy enterprises. Ensuring good nutrition and keeping abreast of herd health – catching issues before they can become a problem – contributes to good fertility which, in turns, helps to maintain a good CI. Calculating reductions in GHG emissions is a complex process, with the offset of milk or meat often having a significant effect in addition to animal management and system type. Reproductive traits such as CI not only help to increase efficiency and reduce GHG emissions but can also improve the profitability of the business too. As such, these aspects form an important part of a holistic strategy for reducing GHG emissions from the livestock production industry.

Summary

The concept of reducing the C footprint of farming is complex – with reductions in one area often causing increases in another. Whilst strategies such as reducing concentrate feed or time to slaughter may appear logical and straight forward, but to achieve target weights and ensure good ADG livestock need to be finished on an energy-dense, nutritionally complete diet, which is particularly important to accelerate growth and reach slaughter quicker. However, this method is expensive for the farmer if concentrates have to be bought in and results in a variety of other issues. A similar trend may be observed in reducing concentrate feed – growth may be slower, and animals have more time in which to produce emissions as well as high forage diets giving rise to more CH_4. Calving interval on the other hand, should form an important part of a more holistic strategy tackling fertility and productivity in dairy and beef herds. Sticking to optimum CI and AFC results in more calves per cow per year leading to a reduction in GHG production per unit of beef or milk. Studies also frequently note that other methods such as producing homegrown feed and implementing selective breeding programmes to increase feed efficiency, fertility or animal health will also pay dividends – both in profits and potentially decreased GHG emissions. Many farmers are already making improvements in these key areas to boost productivity and business efficiency, which can have the knock-on effect of reducing GHG emissions by offset.

Action points

- *Breeding for efficiency*: Focusing on feed efficiency, fertility and health in selective breeding strategies has the potential to reduce GHG emissions by offsetting them with more product.
- *Stay abreast of animal health*: Identifying issues, such as lameness, as early on as possible will not only reduce veterinary costs but will set the animal up to produce the maximum amount of meat or milk and potentially extend their productive life.
- *High quality forage*: High quality, home grown forage can help to reduce reliance on bought in concentrates, reducing the C footprint of the business and the cost of feed whilst allowing tailored and targeted nutrition for animals.