Farming for 1.5°

Independent inquiry on farming and climate change in Scotland

Livestock breeding and genetics and greenhouse gas emissions

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BACKGROUND

Selection between breeds or strains, crossing breeds or strains, and selection within breeds or strains are three well-established means of altering livestock performance (yields of milk, eggs, meat, fibre, feed use, reproductive performance, and increasingly resistance to disease etc)[1]. Some molecular genetic technologies are already augmenting these approaches in industry breeding programmes (e.g. through so-called genomic selection which uses DNA-based profiling to help identify animals with favourable genotypes for traits of interest) and others are under development that may do so in future (e.g. gene editing, currently largely an experimental approach in farmed animals).

Choosing between breeds or crosses produces one-off changes in performance; genetic selection within breeds can produce ongoing, often smaller but cumulative, annual changes in performance. Together these approaches, alongside developments in nutrition, management and health, have produced dramatic changes in livestock performance over the last few decades. For example, dairy cow yields in the UK have increased by around 3-fold in the last 60 years, with much of the change in recent decades coming from selection within the predominant Holstein breed. The value of that change is estimated at £2.4 billion over 20 years. Even more dramatic genetic changes have been recorded in pigs and poultry. Most UK pig, poultry and dairy producers source elite breeding stock from leading multinational breeding companies (via artificial insemination (AI) bulls, in the case of dairy). Despite advanced genetic evaluation systems and breeding indexes having been available for beef cattle and sheep in the UK since the 1990s, with a few notable exceptions there has been a much lower uptake than in other sectors and by international competitors.

A focus on breeding for production traits alone has often led in the past to unintended consequences for animal health and welfare. Most modern breeding programmes include a broader set of goals, including health and welfare, and increasingly environmental impact. The trend to broadening goals started in Scandinavia, with significant and ongoing Scottish research contributions in all major livestock species from the 1980s to the present.

IMPACTS OF BREEDING ON METHANE EMISSIONS

Generally, at a farming system level, changes in livestock performance lead to reductions in feed and other resources used per kg of product, and hence in GHG per kg product too – so-called GHG emission intensity. For instance, a comparison of US dairy systems in 1944 and 2007 estimated that modern systems required 21% of the animals, 23% of the feedstuffs, 35% of the water, and only 10% of the land per billion kg of milk produced[2]. The 2007 systems produced 24% of the manure, 43% of methane, and 56% of the nitrous oxide per billion kg of milk compared with 1944 systems. Selection alone in broiler chickens (chickens bred for meat production) is estimated to have reduced feed required per kg of weight by around 35% over 25 years[3], with corresponding savings in land use and GHG emissions per unit product.

In countries with important ruminant livestock sectors, breeding has a particularly important role in efforts to reduce GHG emissions. Ruminants have a unique ability to digest fibrous feeds like grass and forages, thanks to microbes in the rumen, but some of these microbes produce methane in the process – a potent, albeit relatively short-lived, GHG. This ‘enteric’ methane from ruminants is a major source of GHG. Hence, a key future objective for ruminant systems is to reduce methane emissions per unit of product or in absolute terms.

There are major opportunities in the Scottish beef industry to reduce emissions and emissions intensity by optimising integration with the dairy sector, by optimising age and weight at slaughter, improving feed and other resource use efficiency, and reducing losses from disease or poor reproductive performance. There is also much interest internationally in several dietary additives that can significantly reduce methane emissions, with some of these undergoing regulatory approval.

Breeding is a powerful tool to change these animal characteristics, as mentioned above. Recent SRUC research on commercial abattoir, Cattle Tracing System and Beef Efficiency Scheme data shows major opportunities for producers to improve physical and economic performance of breeding and finishing stock through more effective selection. Benefits of up to 75% in economic performance and 73% in GHG reduction are estimated over a 10 year period, with selection on currently available tools[4].

Hence, a key recommendation to indirectly reduce GHG emissions intensity in the Scottish beef and sheep sectors is to dramatically increase the use of existing breeding tools (EBVs and selection indexes) appropriate to the enterprises concerned (breeding vs finishing etc). This is likely to be enhanced by supply chain and/or government recognizing and incentivizing this (e.g. by driving use of sires in the top decile or quartile of relevant EBVs/indexes; some further desk-based research is needed on the link between these measures and GHG emissions saved, to ‘calibrate’ any incentivization).

Additionally, there is growing interest in further developing breeding programmes to directly target methane emissions. There is good evidence of heritable variation in methane emissions in cattle and sheep. However, there are complexities in measurement at scale, and potential unintended consequences of selection unless relationships with other traits of interest are understood and accounted for. For example, there is a strong positive association between dry matter intake and methane emissions. So, selecting for reduced emissions alone is likely to reduce intake which could impair other aspects of performance. This could be especially important in breeds and strains adapted to low quality diets – an important attribute in reducing competition by livestock for feed suitable for human consumption.

The 'gold standard' for measuring emissions is respirometers – essentially enclosed animal houses where emissions can be measured over several days. While valuable for research, these cannot accommodate the number of animals that need to be measured for breeding programmes for cattle, although mobile respirometers are being used for sheep. Hence, there is a great deal of effort globally to identify cost effective, practical techniques for estimating individual animal methane emissions for use in breeding programmes, including notable contributions from research groups in Scotland. The techniques being investigated include body-worn, food station-mounted and free standing laser-based breath sampling, mid-infrared analysis of milk, rumen sample chemical composition and microbial genetic analysis, mobile respirometers, as well as the use of proxies such as feed intake, or proxies for this, including feeding behaviour.

Over the last 12 years or so, genomic selection has begun to revolutionise livestock breeding. Genomic selection involves selection of breeding animals based on the use of genome-wide genetic markers[1] to estimate breeding values. Genetic markers are DNA-based tests showing the particular bases present at specific sites in an animal's genome – its entire sequence of DNA. The relationships among genetic marker genotypes and animal phenotypes are first measured in a 'reference population', in order to then predict breeding values of selection candidates from genotypes only, or a combination of genotypes and performance records from the animal itself or its relatives (so-called genomic breeding values). A further benefit of genomic selection is that comprehensive recording of traits that are difficult or expensive to measure in commercial herds or flocks – like feed intake, methane emissions or disease resistance – can take place in the reference population, allowing prediction of genetic merit in other animals from genotypes alone. Genomic selection is superseding progeny testing in the dairy sectors of most industrialised countries, as it allows earlier and more accurate estimation of genetic merit of bulls. Likewise, it is becoming widely used in pig and poultry breeding and in some beef and sheep programmes, with benefits in accuracy and range of traits addressed.

Recent research from Wageningen University and Research in the Netherlands[5] predicted that continuing selection on the current NL national dairy breeding index would lead to a 13% reduction in methane produce per kg of milk by 2050, without direct measurements of methane emissions. However, by adding direct measurement of cow methane emissions and putting greater emphasis on reducing methane, reductions of up to 29% could be achieved by 2050. Work is now underway in NL to measure cow emissions on 100 farms using methane 'sniffers' to provide sufficiently accurate data for bull selection by one of the major breeding companies. One of the drivers for greater emphasis on reducing methane emissions in NL is the possible introduction of a carbon tax. Also, some companies in NL pay a premium for milk from farms reducing methane emissions[6].

With most dairy breeding programmes in industrialized countries, including the UK, now selecting animals on similar indexes to that currently used in NL[7,8], and widespread international use of the top AI bulls, it is reasonable to assume that similar indirect gains in GHG emissions intensity are being achieved widely. Scottish farmers could benefit from breeding programmes that directly address methane emissions though purchase of semen from dairy bulls tested in other countries. However, benefits are likely to be higher in dairy cattle – and especially beef and sheep where there is far less international exchange of breeding stock - from accelerating ongoing local research, and involvement in international consortia, to develop and test these approaches here.

Recent research by SRUC, The Roslin Institute, University of Edinburgh and The Rowett Institute, University of Aberdeen has identified microbial genes with significant impact on methane emissions. 'Rumen microbiome-driven breeding' using genomic selection based on the abundances of 30 microbial genes is expected to led to a reduction of up to 6% per annum in methane emissions[9,10,11]. With continuous selection this is expected to result in cumulative gains over time. Work is in progress to further develop and test this approach, and importantly to explore relationships with other traits of interest.

With a long history of research on design of breeding programmes and selection tools in most farmed species, networks of research farms, comprehensive databases on key livestock traits (e.g. from the SRUC Langhill herd and industry recording schemes) and internationally-leading research on approaches and methods for reducing emissions from livestock, Scottish research institutions are well placed to support accelerated innovation in the livestock sector. Recent industry initiatives such as the Beef Efficiency Scheme, some breed society initiatives involving genomic selection, and farmer-led innovation groups such as Fastbreeders, are generating comprehensive phenotypes and genotypes.

We recommend

- Greater industry and government efforts to connect and support these initiatives, thereby:
- Creating a ruminant livestock breeding 'innovation ecosystem', to accelerate development of selection programmes and tools (e.g. reference populations; other tools to enable genomic selection, such as 'SNP [single nucleotide polymorphism] keys' that allow genotyping of the most relevant subset of genes, associated data handling and processing capability) targeting GHG reductions, resource use efficiency, product quality, health and welfare and in locally-appropriate systems and breeds.
- Further development of breeding indexes for ruminants that include reducing methane emissions (intensity or ideally in absolute terms) as part of the breeding goal, and accommodating a range of proxy measures of methane emissions.

RELATIONSHIP BETWEEN GHG EMISSIONS INTENSITY AND TOTAL EMISSIONS

Improving (i.e. reducing) GHG emissions intensity appears to be desirable from environmental, resource use efficiency and economic perspectives. However, if improvements in efficiency lead to increased consumption (Jevons Paradox) and production, then total emissions may not fall at all. For example at a farm level, savings in feed or reproductive efficiency may simply lead to greater output, and hence higher total emissions, albeit with lower emissions intensity.

Hence, it is important to find levers that continue to produce improvements in GHG emissions intensity across the farming sector while also achieving reductions in total emissions.

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