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CLIMATE CHANGE MITIGATION THROUGH GENETIC IMPROVEMENT – A DEEPLY WORTHWHILE CHALLENGE IN THE SPIRIT OF JOHN VERCOE

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INTRODUCTION

It is an unexpected and considerable privilege to have been asked to deliver the John Vercoe Memorial Lecture at this Conference. John Vercoe contributed to livestock development both in Australia and globally, through research that was rigorous, insightful, and practical, and more broadly through his commitment to effective multi-disciplinary collaboration and leadership. That commitment meant that problems that were complex or even wicked (Wittel *et al.* 1973) at the time became tractable and yielded insights that could be implemented by breeders and farmers, and established solid foundations for further progress. Further, he did not shy away from challenging orthodoxy – the push to introduce and use *Bos indicus* genetics in Northern Australia in the face of considerable industry opposition being an outstanding example. Similar courage will be required in tackling climate change, given how deeply embedded in human activity the drivers are of that change and the inevitable extent of vested interests confronted.

This paper addresses the challenge of climate change mitigation through genetic improvement, focussing on animals (but acknowledging that genetic improvement of plants is also targeting methanogenic properties) attempting to highlight elements of how we can tackle that challenge drawing on inspiration from John Vercoe's practical philosophy. The paper does not attempt a review of all activity, research, publications etc with any detail; rather, to consider how genetics can contribute to tackling climate change, to outline key challenges in doing that, and suggest how our genetics community can contribute – in very positive ways.

THE CHALLENGE

Climate change arising from global warming is widely accepted as an existential challenge to humanity and indeed life on this planet (IPCC 2022). The underlying driver of the warming is increasing CO2 concentrations in the atmosphere, which result from a range of sources including burning fossil fuels, deforestation, construction, and others. Contributing also to warming, is methane. Indeed, almost half of recent warming can be attributed to rising emissions of methane from energy, waste and agriculture. Sources of methane emissions include those from enteric fermentation in the rumen, which are estimated to contribute nearly 30% of anthropogenic methane.

Methane emission from enteric fermentation in the rumen are potentially able to be reduced, since methane represents unused energy consumed by the animal. The questions for focus then become:

- How might methane emissions be reduced i.e. by what methods or approaches?
- How much reduction might be possible?
- What costs are likely to be involved?
- What are the prospects of success, and what is needed to ensure success?

Together, the threats generated by climate change, the complexity of the economic or activity systems contributing to it – including the ubiquitous dependence of human activity on conversion of energy, and the uncertainty around the range of possible approaches, mean that climate change

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mitigation can be rightly considered a complex, or more probably, a "wicked" problem (Wittel *et al.* 1973).

Reducing emissions from enteric fermentation must focus on the anaerobic microbes in the rumen – the Archaea, and in principle either reducing their abundance and/or activity, and/or preventing/inhibiting them from generating methane. The main approaches to achieving these outcomes are:

- Supplementation of diets with molecules, compounds or feedstuffs that have these effects
- Developing vaccines against the specific microbial species
- Breeding animals that generate less methane

Assuming that one or more of these can be developed and deployed, they must be able to be deployed at very wide scale, and it is almost inevitable that interactions and synergies between them will arise and need to be understood.

Immediately we can see links back to themes of John Vercoe's life – the willingness to tackle complex or even wicked problems, the need for rigorous and insightful science coupled with the imperative for practical outcomes, and the need for genuine multi-disciplinary approaches.

GENETICS AS AN APPROACH TO METHANE MITIGATION

The strategy for deploying genetic change as a means of tackling a problem is well-known (e.g. Cunningham 1979; de Haas *et al.* 2021), consisting – adapted to use of genomics - of:

- Define the breeding objective, including both the traits being targeted and the value of changing each
- Measurement of the trait(s) or correlated predictor traits, which may include developing methods of measurement
- Estimating genetic parameters for the trait(s) and any correlated criterion and objective traits in the population, utilising both pedigree and genomic information
- Predicting breeding values for candidates, potentially in both the nucleus or seedstock sector and the commercial sector, relying on pedigree and phenotype, pedigree and phenotype and genotype, or genotype alone
- Selecting parents, and in parallel selecting animals for commercial production, both based on breeding values (which may be expressed in different format for different sectors of the value chain)

Applying this strategy may involve nuances such as utilisation of mate selection and coupling with reproductive technologies, and underlying the implementation is the question relevant to all genomic selection, of how much and where (what traits) to invest in ongoing phenotyping – especially relevant where the trait(s) is hard-to-measure (Banks 2022).

While this algorithm is applicable to any trait or combination of traits, considering its use in tackling methane mitigation brings some challenges:

- There is considerable debate around what the breeding objective trait is – absolute methane emission (i.e. gm per day), methane yield (i.e. per unit feed intake), or methane intensity (i.e. per unit product). Consequences of selection for each of these have been examined (e.g. van der Werf 2023), but as yet there is no consensus on the best approach, and the debates around the question are often emotionally charged, (and hindered by limited knowledge of the relevant genetic parameters), in part because many stakeholders either fear or cannot comprehend a situation where the outcome would be to reduce the rate of improvement of food (or fibre), and because mechanisms for credit or debit for emission level are absent or embryonic in most jurisdictions.
- There is no clear market signal in place, in any species or region, in the sense of a price of unit change in the trait leading to a payment or cost to the farmer. Options for dealing with this fact include:

- Using current market price
- Conducting sensitivity analysis, varying price from zero to some large value
- Using such sensitivity analysis to develop desired gain options

Interestingly, it is straightforward to derive an implicit carbon price from responses under consideration such as herd reduction, and those prices are orders of magnitude higher than any current market price.

These uncertainties around the price feed directly into challenges around funding for phenotyping: if methane is considered an externality of the whole food production system, the most efficient mechanism economically is a Pigouvian tax (analogous to an end-point royalty, or levy), usually requiring some form of government intervention. Individual breeder and/or producer stakeholders may invest in phenotyping intending to create a point of difference, but in the absence of a widespread carbon price, will likely have to either invest in additional marketing to maintain that point of difference, and/or underinvest in phenotyping.

- There is no single or obviously superior measurement technique. Methods in use or under development for individual animal measurement include respiration chambers, Greenfeed, sniffers, portable accumulation chambers (PACs), MIR-prediction, wearable devices. These vary widely in cost and practicality and will have different genetic parameters (ICAR Feed and Gas https://wiki.icar.org/index.php/Section_20_%E2%80%93_Methane_Emission_for_Genetic_Evaluation#Sub-sections, Van Breukelen, 2023).

  The fact that different measurement methods have different suitability in terms of where they can be deployed means that methane phenotypes will inevitably be collected in different production systems – ranging from barns with TMR feeding, through to extensive grazing, which means that there will inevitably be a range of criteria (measurement method x diet (quality and quantity)), which could be an issue even within a species in a region, but will certainly impact efforts to combine data across systems.

  In “normal” animal breeding where the focus is largely on selection within a population, such diversity of criteria is not a major problem, but for a trait that is currently expensive to measure and for which there would potentially be benefit in combining data from different sources, the challenge of building sufficiently robust genetic parameter sets will be relevant. The INTERBULL approach to this challenge provides an example of a solution (INTERBULL, https://interbull.org/index).

This list is likely not complete, but highlights aspects which require careful thought and analysis of options, and clear communication of those options and their consequences: the contributions from the community of animal breeders will be pivotal.

At the same time, initial modelling work suggests that valuable reductions in methane emission can be achieved, with 1% reduction per year without significant loss of gain in other traits being a realistic estimate. To some this sounds unhelpfully small, but it is of course cumulative and permanent, and delivers the considerable and valuable consequence of steadily reducing the extent of requirement for alternative approaches, such as expensive dietary supplements.

THE GLOBAL METHANE HUB – ONE INITIATIVE, INCORPORATING THE GENETICS APPROACH

It is impossible to cover the range of activities and initiatives that have been conducted or are underway across the globe directed in some way to mitigating climate change – even focussing solely on methane the list would be extensive. But it is worth noting that these include:

- Modelling studies to estimate effectiveness of different technologies (e.g. FAO 2023)
- Economic analyses of different technologies (e.g. Moran *et al*. 2007)
- Policy development and in some cases implementation (e.g. Denmark)
- Development of diet supplements (e.g. Bovaer/3NOP, Asparagopsis)

- Modelling studies investigating genetic approaches (e.g. Cottle *et al.* 2009; de Haas *et al.* 2021; Barwick *et al.* 2019; van der Werf 2023)

Interestingly, despite some political hurdles, Australia and NZ have been active in scientific research around climate change for a considerable time, and in terms of preparedness for signals or triggers of policy and/or market change, are probably as well placed as any countries. That activity over about two decades has included significant government and industry investment (e.g. Meat and Livestock Australia programs, the NZ Greenhouse Gas Consortium, and the Net Zero CRC in Australia).

This background does not imply any widespread agreement on what should or could be done, but does mean that there is a basis of some knowledge particularly relevant to issues of measurement, effects of additives, and early basis for clear thinking on the genetic approach.

Included in this foundation are estimates of emissions from different classes of livestock and different regions (https://www.fao.org/faostat/en/#data/GT). The most significant message from these estimates is that 76% of estimated emissions are from the developing world, and almost 70% are from other than dairy cattle.

One response to this mix of causes for cautious optimism, but against a background of confusion and debate, has been the growth of globally active philanthropy: building funds for potential investment into initiatives targeting climate change mitigation. One example is the Global Methane Hub (https://www.globalmethanehub.org/), whose initiatives include an Accelerator Program, focussed on emissions from enteric fermentation – i.e. ruminants. (NB: the author is a member of the Scientific Oversight Committee for the Accelerator Program).

The Accelerator Program is investing upwards of $US175m over 5 years into:

- Vaccine development,
- Additive development, in particular into understanding their effects,
- Fundamental rumen microbiome research and research infrastructure, and
- Genetic approaches, including interactions with other approaches (e.g. additives), and use of rumen microbiome information in predicting animals' genetic merit.

The genetic component of the Accelerator Program is well underway, with coordination provided by the team at Wageningen University and research lead by Prof. Roel Veerkamp. Progress in the year since the initiative commenced includes:

- Work considering strategy for resource allocation (between species, between regions)
- Projects focussed on collecting methane phenotypes to build genomic reference populations, aiming at c. 100,000 phenotypes collected with corresponding genotypes
- Structured rumen microbiome sampling, to massively expand resources for research into the microbiome, and to augment genomic prediction models
- Design for a global database of phenotypes and associated information, to be accessible for research and genetic evaluations
- Contribution to validation of measurement tools
- Initiating a program of documentation coupled with communication and extension, covering a wide range of topics relevant to breeding for reduced methane emission (this and the previous point are being progressed in close collaboration with the ICAR Feed and Gas Working Group)
- Methods for accounting data, to underpin fair-share principles for access to pooled data
- And extending the program to address current gaps in regional and species coverage

It is anticipated that the program will contribute to development of models for incentivising on-farm change and to government policy development, and to farm- and national-level monitoring (such as by using genetic trends as one measure of change).

An obvious message from the global estimates of emissions is that the major proportion of estimated emissions derive from livestock in the developing world, where infrastructure and systems for genetic improvement is often limited or absent. This fact, in addition to resonating with the focus of much of John Vercoe's research and science leadership, will continue to be front of mind, but it is hoped that encouraging and supporting the development of a global knowledge commons, and shared resources wherever possible, will help address this challenge.

THE CHALLENGE, AND THE RESPONSIBILITY

This brief outline barely scratches the surface of the breadth and rapid growth of activity around methane mitigation, even if we limit our attention to genetic approaches. Climate change is quite literally, the existential challenge of our times. Our community of animal and plant breeders, working together with rumen microbiologists, can play a far more significant role than is currently appreciated, or may ever be acknowledged. We are fortunate that the tools and knowledge available, including in particular genomic selection, offer control, in terms of optimising trait change, and speed of change. Further, the global community of geneticists is characteristically open and amenable to sharing knowledge and resources, including data, and in general is as much motivated by human and planetary good as by financial rewards.

Apart from the direct contribution via implementing effective genetic improvement that reduces methane, our community can make a massive contribution through something less tangible, but equally important: through clear, honest, open communication of what is possible, what is being learned about what is possible, and what precisely are any trade-offs that may need to be evaluated. The theory we work from is one of humanity's finest achievements, and offers clarity that will be vital in the swirling, confusing world of market failures, livelihood fears, trading behaviours etc.

Deploying genetics methods to tackle the climate crisis should be a very significant element of humanity's response, and we have the opportunity to build and deliver a "moonshot" program for our and all time (Mazzucato 2018). Truly, we can walk in the footsteps of John Vercoe, and there can be no greater privilege or opportunity.

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