Proc. Assoc. Advmt. Anim. Breed. Genet: 24: 15-18

THE CONTRIBUTION ANIMAL BREEDING CAN MAKE TO INDUSTRY CARBON NEUTRALITY GOALS

S.J. Rowe[1], S.M. Hickey[2], P.L. Johnson[1], T.P. Bilton[1], A. Jonker[3], W. Bain[1], B. Veenvliet[1], G. Pile[1], B. Bryson[4], K. Knowler[4], N.C. Amyes[2], S.A. Newman[1] and J.C. McEwan[1]

[1]AgResearch, Invermay Agricultural Centre, Mosgiel, New Zealand
[2]AgResearch, Ruakura Agricultural Centre, Hamilton, New Zealand
[3]AgResearch, Grasslands Research Centre, Palmerston North, New Zealand
[4]AgResearch, Woodlands Research Farm, Invercargill, New Zealand

SUMMARY

In New Zealand, ~84% of methane and ~30% of total greenhouse gas emissions are derived from enteric emissions from grazing ruminants. Here, we show a simple estimation of the impact of implementing a national breeding scheme in sheep to reduce methane emissions, based on real on-farm figures. We demonstrate how a modest change in breeding for environmental traits can lead to substantial changes in ruminant emissions. Currently there is uncertainty around how methane emissions at the farm gate will be valued. Our estimates show that breeding although slow, is a viable option to make real progress towards carbon neutrality with a very high rate of return on investment and a very modest cost per tonne CO_2 equivalents saved regardless of accounting method.

INTRODUCTION

Methane is a greenhouse gas associated with climate change and approximately 84% of methane emissions in New Zealand are produced from grazing livestock (MfE 2020). Reducing methane emissions from livestock is therefore of environmental and economic importance. Ruminant animals primarily produce methane as a by-product of the complex microbial fermentation process in their rumen that breaks down feed to volatile fatty acids, which are absorbed through the gut wall and are a major source of energy for the animal (Matthews *et al.* 2019). Although the mechanism by which the host controls this fermentation process is not well understood, heritable individual variation has been shown to exist and methane mitigation has been shown to be possible through breeding (Pinare-Paino *et al.* 2013, Jonker *et al.* 2018, Lassen *et al.* 2016). The impact of changes in methane emissions is generally measured by converting to carbon dioxide global warming equivalents (CO_2e). The Global Warming Potential (GWP) of a greenhouse gas is its ability to trap extra heat in the atmosphere over time expressed as CO_2e. This is most often calculated over 100 years and is commonly referred to as GWP_{100}. While GWP_{100} is the accepted metric for describing the warming impact of greenhouse gases, it uses a single scaling factor that doesn't account for methane being a short-lived gas in the atmosphere (Lynch *et al.* 2020). Recently, the use of warming potential or $GWP_{w.e.}$, based on warming equivalents, has been proposed. This accounts for the behaviour of change of methane emission in the atmosphere, and on its contribution to global warming over time.

Over the past decade, two small sheep flocks (n = 100 ewes) have been selected for divergent methane yield, with low-methane sheep currently emitting 10-12% less methane than the high-methane animals (Rowe *et al.* 2019). Furthermore, methane emissions have been measured in a research flock run under commercial conditions and methane breeding values included in a maternal selection index at a hypothetical cost of NZD$100 per CO_2e using GWP_{100}. The development of portable accumulation chambers (PAC) to phenotype sheep and the demonstrated success, together with funding from the Pastoral Greenhouse Gas Research consortium has been used to successfully roll out methane measures on commercial farms. Research breeding values for methane emissions have been implemented within the national breeding scheme - Sheep Improvement Limited (Newman, 2009 Beef and Lamb New Zealand 2020). The realised genetic progress made in methane breeding values has been used to estimate the impact of measuring a proportion of the New Zealand commercial flock.

MATERIALS AND METHODS

Animals. Data to estimate genetic gain was available from multiple sources. Genetic parameters were based on 15,000 methane records from sheep measured through portable accumulation chambers from flocks across New Zealand. Flock records for methane emissions recorded from 2009 and performance traits recorded from 1995 to 2020 were also available for a 750 ewe, composite maternal flock (research flock 2638) where selection on an index that included methane was implemented in 2018.

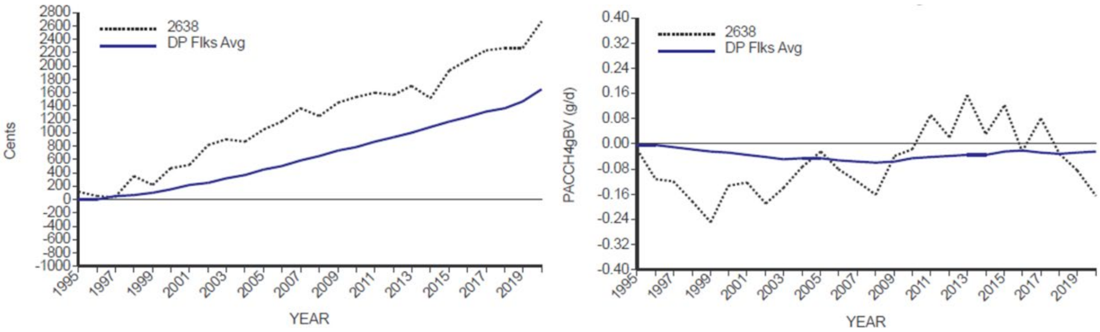
Over the last two years over 5,000 sheep have been measured across ram breeders' farms for methane emissions (grams CH_4 per day) using PAC. The number of sheep measured per farm varied from 84 to 268. This demonstrates that given current infrastructure, that ~5,000 measures are physically possible across the national flock annually. Based on this, we assumed that ~2.5% of all lambs born into the stud tier (n=~200,000) could be measured annually.

For predicting the impact of breeding for low methane, we assumed a 20-year time horizon with a lowering of emissions through a combination of phenotyping and genomic prediction. We assumed no reduction of emissions for the first 5 years in the commercial flock due to genetic lag effects and a starting adoption rate of 0.3, which is the current penetration of genotyping in NZ sheep flocks, increasing adoption by 0.1 per year until 100% adoption in the breeding tier in year 8. We assumed 200,000 lambs born each year into the stud tier with 2.5% of these (n=5,000) measured for methane and the remainder genotyped. Commercial production based on 2020 figures assumed 16.85 million breeding ewes producing 8390 kt CO_2 equivalent. Methane was valued at NZD$50, $100 and $200 per tonne CO_{2e}.

RESULTS AND DISCUSSION

Figure 1 shows that in a research flock (2638) farmed under commercial conditions, implementation of methane into the index using a GWP_{100} and NZD$100/tonne CO2e led to a reduction of methane emissions by 1-2% per year whilst still maintaining genetic gain in the maternal index (without accounting for any gains made in methane).

Figure 1 Genetic trends for New Zealand Maternal Worth (NZMW) index (cents) (left) and breeding values for methane emissions (PACCH$_4$gBV measured in g CH_4 per day) (right) in research flock 2638 and average recorded maternal flock

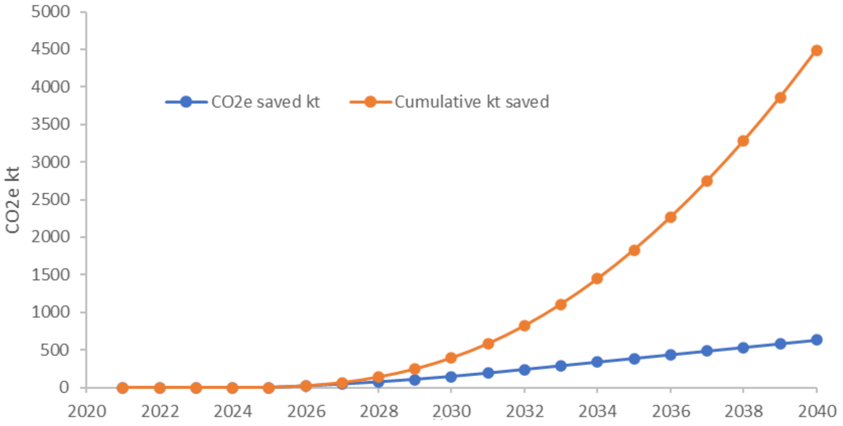


Blue line denotes average recorded maternal flock (DP Flks Avg). Methane emissions were measured in the 2638 flock from 2009 and were added to the selection index of flock 2638 in 2018.

Variation in breeding values for grams of methane emitted for all commercial flocks was similar across farms, commonly ranging from ~-1.5g to +1.5g grams per day. This suggests that there is sufficient variation segregating in the general population for genetic improvement.

The commercial and physical impact of a national breeding scheme to lower methane emissions was estimated as 0.58%/year using genomic selection. After 20 years, annual methane production in 2040 was predicted to have reduced by 7.5% per annum saving a total of 4490 kt of CO_2e over the 20-year period (Figure 2) with a cumulative saving of CO_2e assuming GWP_{100}.

Figure 2 Predicted annual and cumulative savings in methane emissions measured in carbon dioxide equivalents (kt) based on a 0.58% genetic gain per year



Assuming 5,000 sheep measured annually, methane measures at a cost of NZD$30 per measure and genotyping at a cost of $25 per animal, the total cost of implementing the scheme over the 20-year period including additional genotyping of stud animals by breeders was estimated at NZD$31 million. This includes capital expenditure of NZD$200,000 on PAC measuring equipment. The marginal cost of reducing a tonne of CO_2e was estimated at $1.72. This includes losses made in years 1 to 5 due to genetic lag and low adoption rates in the early years. Assuming a tax rate of 28%, and cost of borrowing at 10%, the internal rate of return on a total investment of ranges from 42 to 80% for GWP_{100} to 64-111% for $GWP_{w.e.}$ depending on the costs per tonne of CO_2e (Table 1).

Table 1. Internal rate of return for 0.58% genetic gain per year expressed at a national level

	$tonne CO2e	**ΔG/year%**	**NPV(10%) $M[1]**	**IRR[2]**
GWP_{100}	50	0.58	41.6	42%
	100	0.58	94.1	60%
	200	0.58	199.3	80%
GWPw.e.	25	0.58	111.3	64%
	50	0.58	233.6	85%
	100	0.58	478.3	111%

[1] NPV=Net Present Value, [2] IRR =Internal rate of return

CONCLUSIONS

We have demonstrated a 1-2% reduction per annum in our commercial research flock since methane breeding values were included in the index, whilst maintaining genetic gain for all other traits. We have also estimated that if we achieve less than one half of this reduction in the breeding tier in the national flock, given likely adoption rates, and including genetic lags in the deployment of improved livestock, we can use breeding to make a substantial contribution to methane mitigation at a very low cost to the industry. These benefits have been made achievable by the development of low-cost high throughput phenotyping for methane combined with the widespread adoption of genomic selection. Sheep account for 1/3 of enteric emissions in New Zealand with cattle contributing most of the remainder. There is currently a barrier to achieving reduction of methane emissions in cattle due to a lack of high throughput measurement technology. If this barrier were overcome, benefits from breeding would be potentially much greater than for the sheep industry and more straightforward to achieve, given widespread use of artificial insemination and the much lower effective population size.

ACKNOWLEDGEMENTS

This work was funded by the New Zealand Ministry for Primary Industries, the AgResearch Strategic Scientific Investment Fund, the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), the Pastoral Greenhouse Gas Research Consortium (PGgRc), Beef and Lamb New Zealand and various sheep breeders in New Zealand.

REFERENCES

Beef and Lamb New Zealand. (2020) https://beeflambnz.com/news-views/low-methane-emitting-sheep-reality-nz

Jonker A., Hickey S.M., Rowe S.J., Janssen P.H., Shackell G.H., Elmes S., Bain W.E., Wing J., Greer G.J., Bryson B., MacLean S., Dodds K.G., Pinares-Patiño C.S., Young E.A., Knowler K., Pickering N.K. and McEwan J.C. (2018) *J. Anim. Sci.* **96**: 3031.

Lassen J. and L∅vendahl P. (2016) *J. Dairy Sci.* **99:** 1959.

Lynch J., Cain M., Pierrehumbert R. and Allen M. (2020) *Environ Res Lett*. **15**: 4.

Matthews C., Crispie F., Lewis E., Reid M., O'Toole P.W. and Cotter P.D. (2019). *Gut Microbes* **10**: 115.

MfE (2020). New Zealand`s Greenhouse Gas Inventory 1990-2018. In Ref. MFE 1496. Ministry for the Environment, Wellington, New Zealand.

Newman S-A.N., McEwan J.C. and Young M.J. (2009). *Proc. Assoc. Advmt. Anim. Breed. Genet.* **18**: 624.

Pinares-Patiño C.S., Hickey S.M., Young E.A., Dodds K.G., MacLean S., Molano G., Sandoval E., Kjestrup H., Harland R., Hunt C., Pickering N.K. and McEwan J.C. (2013). *Animal.* Jun;7 Suppl **2**: 316.

Rowe S.J., Hickey S.M., Jonker A., Hess M.K., Janssen P., Johnson T., Bryson B., Knowler K., Pinares-Patiño C., Bain W., Elmes S., Young E., Wing J., Waller E., Pickering N. and McEwan J.C. (2019). *Proc. Assoc. Advmt. Anim. Breed. Genet.* **23**: 306.