Proc. Assoc. Advmt. Anim. Breed. Genet. 26: 150-153

METHANE INDEX EXPLORER: OPTIMISING A BREEDING VALUE FORMAT FOR SIMULTANEOUS INCLUSION OF ENTERIC METHANE EMISSIONS IN BREEDING SCHEMES AND NATIONAL INVENTORIES

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SUMMARY

This study developed a method to incorporate portable accumulation chamber methane (PACCH4) breeding values (BVs) into ram selection criteria. The PACCH4BVs of 1349 rams born in 2021 and 2022 were estimated different genotypes inclusions levels and evaluated using a flock-specific selection index. The selection response under nine economic weights (from NZ$0-NZ$200/tonne GWP100 CO2e) on PACCH4 showed that progress depended on selection weight, genotype inclusion level, and between-year variability. A selection weight of between NZ$50 and $100/tonne can reduce methane emissions while not dramatically affecting progress in production traits. However, animals should be PAC measured and genotyped to achieve up to 1% annual reduction in PACCH4BVs. This software is suggested for use as a breeder aid. We also recommend that in the future PACCH4BVs are expressed as percentages to aid end-user and inventory calculators' understanding and interoperability.

INTRODUCTION

Enteric methane (CH_4) emissions present a significant challenge for ruminant livestock production. It has been shown that enteric CH_4 emission is a heritable trait, and breeding is an effective mitigation strategy (Rowe *et al*. 2019). The impacts of breeding for low CH_4 and how to incorporate the trait into a breeding scheme are less well understood. Although most genetic correlations with other traits appear neutral (Rowe *et al*. 2022), an important factor is its implicit relationship with feed intake and live weight: both important traits in national genetic selection programmes. National inventories account for greenhouse gas emissions using standardised formulae published by the Intergovernmental Panel for Climate Change describing ratios of methane emissions to energy intake for given stock classes. Currently, there is an opportunity to co-design national inventories and breeding schemes to ensure that the data from each is interchangeable and independent. A breeding value (BV) is an estimate of the relative genetic merit of an animal. It is used to select parents of future generations. BVs for distinctive characteristics are often combined using economic weights (EW) into a profit index. As breeding is a long-term commitment spanning generations, careful thought must be given before finalizing the format. The primary aim here was to develop a methodology including BV that is fit for purpose for national evaluations, government inventory, and allows breeders to optimise genetic progress for their own flocks and indices in a simple graphical format.

MATERIALS AND METHODS

Estimating indices. The genomic BV (gBV) and indices for the rams born in 2021 and 2022 in the AgResearch Woodlands genetic research flock (Flock 2638) were extracted from Sheep Improvement Ltd (SIL, www.sil.co.nz) database. Results from ram labs born in 2021 and 2022 were analysed separately to assess within flock selection response consistency. The gBVs extracted on 22-Nov-2024 (Job no. 2427567) are called version 5 animal evaluation (AEV5), whereas gBVs extracted on 9-Dec-2024 (Job no. 2434492) are called version 6 (AEV6). AEV5 and AEV6 differ in the analytical method and the number of genotypes used. A total of 744 and 605 animals from the 2021 and 2022 cohorts were analysed, with 384 and 324 recorded for PACCH4. Genotype inclusion varied by evaluation: AEV5 had minimal genotyping in 2021 (0.1%, n=1) but increased to 50.2% (n=304) in 2022. In contrast, AEV6 had high genotype inclusion, reaching 99.3% (n=739) in 2021 and 99.7% (n=603) in 2022. The index utilised for the evaluation of flock 2638 contained the sub-indices of New Zealand maternal worth (NZMW: weaning weight, weaning weight maternal, ewe live weight, carcass weight, number of lambs born, lamb survival, survival maternal) with faecal egg count (FEC: FEC1, FEC2, adult FEC), dag scores (DAGS: lamb DAGS, adult DAGS), meat (MEAT: hindquarter lean yield, loin lean yield, shoulder lean yield, carcass weight yield), and portable accumulation chamber methane (PACCH4). This index is referred to as the NZMW-plus index from here onwards, and the traits' EW (cents) are presented as SIL Technical notes (2022). The code utilized for the analysis and SIL Technical notes indicating EW for the traits are publicly available at https://github.com/AgResearch/MIE.The gBVs for PACCH4BV (expressed as unit g/day per 5 month lamb) were divided by scaled mean PAC emissions and multiplied by a hundred to convert it to a percentage (PACCH4BV%). This latter value is easily understood by breeders and allows transparent changes in BV and on-farm inventory calculator methodology. The conversion of PACCH4BV% to a dollar index value is called here the dual-purpose CH4 (DPCH4) subindex. Nine EW (GWP100 ($/tonne)) for CH4gBV% were assessed (from $0 to $200 in $25 steps) to determine its impact on CH4gBV% and production. A DPCH4 for each EW was calculated. A $100 per tonne of GWP100 CO2e equated to an index value of -681 cents for PACCH4BV and -51 cents for PACCH4BV%. The NZMW-plus+DPCH4 index for each animal and each EW was calculated as the sum of the NZMW-plus and DPCH4 indices.

Potential progress of PACCH4BV%. The linear regression (r^2) between the NZMW-plus index and NZMW-plus+DPCH4 index for each PACCH4BV% EW($/tonne) was estimated, multiplied by a hundred, and was considered as the percentage potential progress in the NZMW-plus index. Similarly, the r^2 between DPCH4 and NZMW-plus+DPCH4 for each PACCH4BV% EW($/tonne) was estimated, and this was considered as the percentage potential progress in CH_4. The reduction of PACCH4BV% per year in each NZMW-plus index was calculated as follows.

$$\text{PACCH4BV\% reduction/per year} = (\text{potential progress in } CH_4\ (\%) / 100) \times \text{Std Dev. PACCH4BV\%} \times (i/L)$$

The intensity of selection (i) was estimated considering a selection of 2% of males (i = 2.421) and 30% of females (i = 1.159) and the generation interval (L) of 3.5 years for females and 1.3 years for males, therefore, i/L of 0.75.

RESULTS AND DISCUSSION

Figure 1 shows the potential progress in the NZMW-plus index and PACCH4BV% under each EW for CH_4 for AEV5 and AEV6 for both years. The selection responses were consistent over years. There was a clear difference in the gains achieved between evaluations. Notably, there was little gain in PACCH4BV% in 2022 born rams until $50/tonne in both AEV5 and AEV6. AEV6 achieved a greater PACCH4BV% progress compared to the AEV5 under all the EW for CH_4 and higher gains were achieved above $100/tonne but with a higher trade-off in the production index gains (NZMW-plus). For example, approximately 30% and 70% gains in PACCH4BV% and production can be achieved, respectively, at $150 EW in born 2021 animals through AEV6.

The per-year PACCH4BV% reductions under each EW are presented in Figure 2. The trends indicate an average 1.00% and 0.52% reduction when an EW of $100/tonne for years 2021 and 2022, respectively. A maximum of up to a 2.6% per-year PACCH4BV% reduction can be achieved in the AEV6. A favourable observation is that even with zero or low index weights on PACCH4BV%, the NZMWplus index used here did not result in a predicted increase in

PACCH4BV% per animal emissions, implying a change in either feed efficiency or a decrease in methane per unit of dry matter eaten, or both. However, further work is required to investigate this aspect.

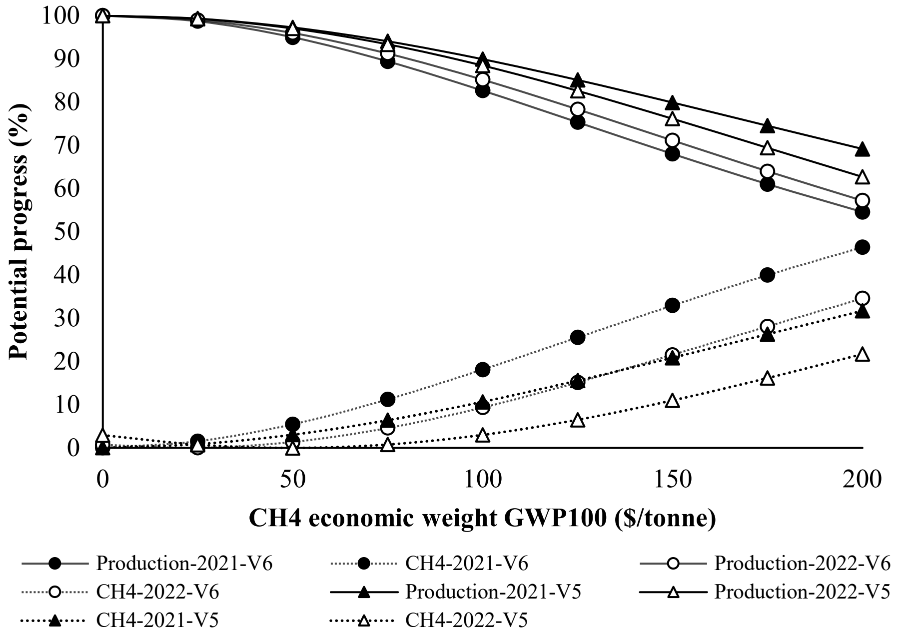

Figure 1. Percentage progress of the methane (PACCH4) breeding values and NZMW+FEC+DAGS+MEAT index (NZMW-plus) in the year 2021 and 2022

The differences in achieved progress in AEV5 vs AEV6 for the same rams can be attributed to the variations in the relationships among gBVs of traits between evaluations and accuracy of estimated gBVs. The gBVs estimated in AEV6 include a higher proportion of genotyped animals (>99%) and, therefore, should possess improved accuracy of estimated gBVs compared to AEV5. The higher genetic gains of PACCH4BV% per year achieved through the PACCH4BVs estimated in AEV6 were closer to what was observed in practice (Booker *et al*. 2024). They also observed that current industry progress in NZMW-plus is only about 50% of its potential so it is possible to increase the NZMW-plus at a faster rate than industry while also decreasing PACCH4BV%. This suggests that the introduction of methane into selection indices should be accompanied by detailed advice on how to also increase overall flock genetic gain. One caveat of this approach is that the EW of the production traits assume all changes in flock methane emissions are captured by PACCH4BV, which does not fully account for increases in lamb survival and lambs weaned.

In this analysis, the gBVs of rams are generated by evaluating the flock data. Therefore, the results obtained are more applicable to the ram breeding flock concerned. This is because genotyping, trait recording, and culling strategies selection indices vary widely, and the process can be implemented when the required genetic parameter estimates between the various subindices are either not available or poorly estimated. Further, the results generated by this method might differ from what is obtained from the selection index theory, given that the latter does not account for the flock-specific genetic parameters and variations in the breed composition of the flock.

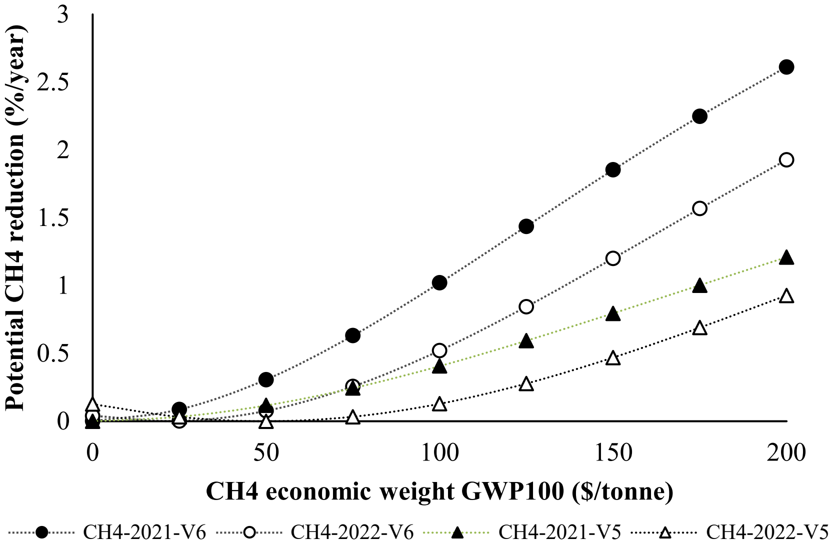

Figure 2. Per year reduction of methane (CH_4) breeding value percentage showing the effect of additional genotypes used in V6 vs V5 for born 2021 and 2022 animals

CONCLUSION

CH_4 mitigation is possible through selective breeding for PACCH4BV%. Greater reductions in CH_4 coupled with a reduction in gain in production traits, therefore, the EW should be cautiously selected. The superior gains achieved by incorporating higher levels of genotypic data for BV estimations suggest that animal evaluations should be based on genotype data if rapid change is desired. Given the stability of the results over the two years evaluated, the PACCH4BV% can be recommended as a desirable form of the PACCH4 trait to include in the selection objectives for mitigating CH_4 emissions.

ACKNOWLEDGEMENTS

Thanks to the Woodlands and Invermay staff who manage and record flock 2638, to the breeders who are now recording methane traits, to B+LNZ Genetics for the breeding value estimates, and to Focus Genetics who funded and encouraged the development of the methane index explorer.

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