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Modelling the industry effects of incorporating direct methane traits into New Zealand national breeding objectives

F.S. Hely[1], D. Kenny[1], C.D. Quinton[1]*, N. Howes[1] and P. Amer[1]

[1]*AbacusBio Ltd, Dunedin, New Zealand;* [*]*Corresponding author: cquinton@abacusbio.co.nz*

Introduction

Genetic selection offers a long-term, cumulative opportunity to reduce enteric methane emissions in New Zealand ruminant systems. As part of the Joint Irish – New Zealand GHG Roadmap project, a modelling toolkit was developed to quantify expected methane mitigation, economic responses, and sector-level impacts arising from incorporating direct methane and feed intake traits into national breeding objectives. This paper reports the results from the second iteration of modelling results, focusing on the New Zealand dairy, beef, and sheep sectors, comparing predicted methane reductions and the opportunity cost of these reductions under multiple carbon price and trait-recording scenarios.

Materials & Methods

This study applied selection index theory (Van Vleck, 1970; Dekkers, 2007), to predict how including direct methane and feed intake traits in national breeding objectives would influence long-term genetic progress in conventional traits and methane. Across the NZ industries modelled, phenotype collection and trait definitions are well underway for sheep (Archer *et al.* 2023), however for dairy and beef these strategies are still under consideration.

Methane Trait Definitions. Methane traits varied across industries in how they are measured and incorporated. Depending on the scenario, we distinguished between predictor traits (directly recorded traits such as methane yield or production) and breeding goal traits (traits expressed in breeding objectives). In sheep, the methane trait modelled was methane adjusted for liveweight and carbon dioxide (CO2), derived from portable accumulation chamber (PAC) measurements (Jopson, N., personal communication). For dairy, where the national breeding objective goal trait is still under consideration, methane yield (g CH4/kg dry matter intake) was modelled as the goal trait, with either methane yield recorded in bulls or methane corrected for production in lactating cows as recorded trait scenarios. In beef cattle, residual methane was modelled as methane output adjusted for feed intake. Residual feed intake was included as a goal trait for both dairy and beef models. Regardless of the index trait definition, the change under selection was converted to a reduction in g CH4 produced per animal per day.

Genetic Parameters. Each selection index model used published genetic parameters where available, supplemented by literature-based estimates for methane related traits. Across species, assumed heritabilities for methane-related traits ranged from low to moderate, and genetic correlations between proxy and direct methane measures were assumed to be moderate, consistent with published estimates. For some species, genetic correlations were estimated from EBV correlations and the base line national breeding objective responses compared with industry genetic trends.

Economic Weight Calculations. Economic weights for the direct methane traits and RFI were derived under two carbon price scenarios of 150 and 550 NZD per tonne CO2e, where these were selected to show low vs high emphasis on methane. The conversion to methane was valued

using the GWP100 multiplier of 27 (IPCC AR6, 2021). Economic weight formulae incorporated carbon price, trait expression, dry matter (DM) intake or days on feed, and discounted genetic expressions.

Selection Index Modelling. Selection index theory was used to estimate expected annual genetic responses across traits under scenarios with and without methane trait inclusion. Key model inputs were economic weights, trait heritabilities and variances, genetic correlations, and recording strategies. Outputs included expected changes per index unit as well as economic and trait unit responses.
An R Shiny tool developed for this project enabled flexible scenario testing including genomic information, varying recording accuracies, trait inclusion decisions, and selection intensities, where this tool produced tabular and graphical summaries for each industry's base and alternative indexes.

Postprocessing to Estimate Industry Impacts. Selection index outputs were converted into industry level impacts using species-specific assumptions on population structure, methane baselines, methane to CO_2e conversions, carbon pricing, and system level aggregation of animal classes. One of the key metrics compared across scenarios was an "opportunity cost" of methane reductions, where this was calculated as the economic difference between the farm profit trait response under the current base line breeding objective, and one incorporating a direct methane trait, divided by the estimated annual reduction in tonnes of CO2e. To estimate the impact of predicted genetic trends at industry scale, geneflow modelling was used to simulate the dissemination of genetic merit through commercial populations over 10- and 20-year periods. This accounted for generation intervals, replacement rates, and the proportion of sires and dams contributing to the next generation.

Results

Sheep Incorporating a direct methane trait into the New Zealand Maternal Worth index (NZMW) resulted in annual methane reductions of 0.9% and 1.8% by 2040 and 2050 respectively at a 150 NZD carbon price (Table 1). At 550 NZD, methane reductions increased to 2.2% and 4.4%, reflecting greater selection pressure on the methane trait. Opportunity costs were modest at 150 NZD per tonne CO2e but increased substantially at 550 NZD, with up to a 36% reduction in response across the current farm profit traits. The inclusion of methane as a trait resulted in minor correlated changes in growth and reproductive traits due to genetic correlations. The scale of reductions in PAC methane was similar to those reported by Rowe *et al*. (2024) where weighting was directly applied to the PAC methane trait.

Dairy. Scenarios incorporating production-adjusted methane measured in cows delivered methane reductions of 2.8% by 2040 and 5.7% by 2050 (Table 1). This scenario outperformed methane yield measured in bulls, which showed lower accuracy. Additional modelling explored the influence of including feed intake (RFI) alongside methane traits. This improved both methane and profitability outcomes, highlighting the potential for joint recording of intake-methane relationships in future breeding programmes.

Beef. Residual methane measured in steers resulted in methane reductions of 0.5–1.0% by 2040 at moderate carbon prices (Table 1). When RFI was included alongside methane, selection responses favoured animals with lower methane emissions and improved feed efficiency, producing positive economic and environmental impacts. Across beef scenarios, methane reductions were modest due to lower selection intensity and smaller national populations relative to dairy and sheep

Table 1. Summary of 2040 and 2050 impacts of incorporating methane traits within sheep, beef, and dairy breeding objectives for both New Zealand. Multiple scenarios are presented to contrast different breeding strategies and economic assumptions. Results shown are the expected impacts relative to the current selection index

Industry by trait	Carbon price (NZD)	Change in farm profit index response (%)	Opportunity cost/tonne CO2e	Reduction annual methane (%)	
				2040	2050
NZ Sheep					
Direct CH4	$150	-4.66	$72.69	0.89	1.77
Direct CH4	$550	-35.78	$223.50	2.21	4.43
NZ Dairy					
CH4 yield in bulls	$150	-0.94	$76.78	0.59	1.18
Adj CH4 females	$150	-0.14	-$133.63	2.83	5.67
Proxy CH4 cows	$150	-2.16	$75.69	1.38	2.75
CH4 yield in bulls	$550	-12.61	$263.37	2.31	4.61
Adj CH4 females	$550	-19.07	$148.51	6.19	12.38
Proxy CH4 cows	$550	-23.87	$242.04	4.76	9.51
NZ Beef					
Residual CH4 steers	$150	-2.53	$21.81	0.51	1.03
Residual CH4 & RFI steers	$150	22.81	-$263.65	0.38	0.77
Residual CH4 steers	$550	-24.18	$120.38	0.89	1.78
Residual CH4 & RFI steers	$550	-2.36	$12.98	0.80	1.61

Discussion

Genetic selection offers a long-term mitigation pathway for enteric methane, but increasing emphasis on methane traits reduces gains in conventional profit traits due to redistributed selection pressure (Hazel, 1943; Walsh & Lynch, 2018). These opportunity costs remain moderate at lower carbon prices but become substantial when strong weighting is placed on methane, highlighting the need for balanced index design to ensure breeder and industry acceptance.

The use of proxy traits such as mid-infrared (MIR), laser methane detector (LMD)–based phenotypes, and other short-duration measurement approaches illustrates the challenge of achieving both scalability and accuracy. MIR-derived traits are attractive for their low cost but depend heavily on strong genetic correlations with true methane emissions, which empirical studies often report as moderate rather than strong (Vanlierde *et al.*, 2018; Breider *et al.*, 2019). When correlations are insufficient, selection response is weakened and may not generate meaningful mitigation. Consequently, proxy traits are most effective when integrated alongside direct methane measurements from systems such as respiration chambers, GreenFeed (www.c-lockinc.com), or PAC (Jonker *et al.*, 2018).

The cumulative nature of genetic progress also means that industry-level reductions emerge slowly as improved breeding values disseminate through commercial herds and flocks. Other modelling studies have also shown that even strong selection produces modest changes in national methane inventories over 10–20 years due to generation intervals and adoption rates (Pickering *et al.,* 2015; Archer *et al.*, 1999).

Key knowledge gaps remain, particularly regarding the genetic relationships between methane, feed intake, and efficiency traits. Further characterisations of genotype-by-environment effects, consistency of methane breeding values across measurement platforms, and potential antagonisms with animal health or resilience traits are necessary to ensure that methane traits remain robust and sustainable components of breeding objectives (de Haas *et al*., 2011; Kenny *et al.*, 2018). Closing these gaps will improve confidence in methane genetic evaluations and strengthen the contribution of breeding strategies to New Zealand's wider agricultural emissions reduction portfolio.

Conclusions

Genetic selection can make a meaningful but modest contribution to methane mitigation across New Zealand's ruminant sectors. The modelling indicates that incorporating direct methane traits into national breeding objectives can achieve reductions of approximately 1–6% by 2050, depending on the species, trait definition, and recording strategy. While direct methane measurement produces the greatest mitigation with acceptable opportunity costs at moderate carbon prices, proxy traits contribute value only when strongly genetically correlated with methane. Given the gradual accumulation of genetic gain and the scale of New Zealand's methane reduction targets, genetic selection should be considered a durable long-term strategy best deployed alongside complementary mitigation tools. Continued investment in measurement infrastructure, direct phenotyping, and research into methane–efficiency relationships will be essential for realising the full potential of breeding-based approaches.

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