Breeding for Sustainability - Fitting environmental impacts into economic selection indexes — John J. Crowley, AbacusBio Ltd.

Sustainability in agriculture has many facets, with greenhouse gas (GHG) emissions currently being a primary focus. Emissions from farmed livestock have been highlighted as a significant source of total global GHG (Gerber et al., 2013) and so this paper deals with the GHG aspect of "Breeding for Sustainability". Recently there has been a significant amount of research undertaken endeavouring to reduce the carbon footprint from animal agriculture. For most producers, families, businesses and industries who depend on livestock for their sustenance and livelihoods, and for consumers of numerous and diverse products that they generate, simply reducing livestock numbers and product produced to achieve GHG mitigation is undesirable (Herrero et al., 2013; Amer, 2022). When a reduction in herd size (local or national) is not possible, emissions per unit of product (emissions intensity; EI) becomes a primary focus. Breeding and genetics exists as a solution to GHG mitigation and holds a medium to high level of impact potential (Lanigan et al., 2019; Hristov et al. 2013). Other solutions such as feed additives, diet lipids, land management, fertilizer use and manure storage etc. all hold different levels of mitigation potential in parallel with genetics (a solution which is cumulative and permanent). The objective of this paper is to highlight approaches for including environmental impacts and considerations in a selection objective, and discuss selection criteria pertinent to that objective.

Selection Criteria

Wall et al. (2010) outlined three main classes of traits that can be selected for to influence a reduction in GHG. Generally we can think of a trait as having a direct effect i.e. emissions from and measured on the animal, or indirect i.e. a reduction in system wide emissions due to a change in a trait. Traits that directly target biological functions of the animal that lead to improved outcomes are the first type of trait described by Wall et al. (2010; Type 1) e.g. Methane Yield (MY; g CH_4/kg DMI). Productivity traits that dilute maintenance (Type 2), and survival traits, and traits that reduce the need for replacement animals and the emissions associated with them (Type 3) are additional options for selection criteria. With these types of traits in mind, we can examine different approaches using these criteria to select for an improved beef carbon footprint.

Current selection for profitability encompasses selection pressure on many of the Type 2 and 3 traits (growth, maintenance, calving interval, longevity) and so it is highly probable that EI is also improving. It would be a worthwhile exercise to (regionally or nationally) quantify the contribution of genetics to GHG mitigation, an exercise which would also set up the framework to move the breeding goal toward a more environmental focus. There are also more appropriate selection criteria that can be defined that make it cheaper and easier for breeding programs to make genetic change in traits that improve both farm profit and which also improve environmental outcomes (Amer, 2012) e.g. age at harvest, and these are usually already in the data we have. Novel traits, (all types) can also be developed. Previously mentioned MY is a key trait given that enteric methane is a large proportion of all beef GHG. The trait shows 15-20% phenotypic variation and is moderately heritable (~0.30; personal communication, Irish Cattle Breeding Federation) and has the opportunity to mitigate large amounts of GHG. The trait holds more importance in a total system if the amount of DMI consumed for beef production does not decline. In certain scenarios (e.g. pastoral systems), improvements in feed efficiency may not result in feed saved, but just the same amount of feed fed to more animals. If total DMI used will not change, selection for enteric methane/kg DMI (Richardson et al. 2021a describes some definitions and considerations) can deliver large carbon mitigation (feed additives currently in development also act on the methane/kg DMI process). On the topic of novel traits, development of breeding values for such conditions as pulmonary arterial pressure (PAP) and the ability to select for traits such as slick can have impacts on survivability and longevity, all of which are cost saving traits and contribute positively to overall EI.

Selection Objective

While current multi-trait selection for profitability is a weighted sum of relevant selection criteria, we can further modify trait selection emphases through changes in breeding objectives and index weightings (Cottle et al. 2011) to achieve reductions in emissions intensity and/or reductions in gross emissions per animal. To facilitate this modification of the breeding objective, GHG emission coefficients (EC) can be estimated on a per trait basis (Amer et al. 2017, Quinton et al. 2018, Richardson et al. 2021b) and appropriately scaled and applied to current breeding values. Assuming the current market rate ($) for carbon as its economic value (EV), current economic weights (EW; EV*discounted genetic expressions (DGE)) per trait can be combined with carbon EV ([EVtrait I - ECtrait i*EVcarbon]*DGE) to calculate a new weighting per trait and in turn can sum to a carbon influenced index. Additionally, or alternatively, one can form a carbon sub index that sits outside other profitability indexes by just estimating carbon economic weights (CEW; ECtrait i*-EVcarbon*DGE) to be applied to relevant traits. The latter subindex approach offers transparency and decouples carbon from profitability in a time where market signals on carbon price related to beef production are weak. Conversely, embedding carbon weights into current indexes allows more direct progress to be made as carbon considerations are explicitly in the objective and will receive selection emphasis regardless, through selection decisions based on available and published economic selection indexes. It is to be noted that the higher the assumed or actual price of carbon is, the higher the relative emphasis will be on traits that influence direct and/or indirect emissions.

The value of index manipulation to decrease selection emphasis on traits that increase gross emissions must also be treated with caution. Reducing EI and reducing gross emissions of a production system require slightly different approaches and considerations. The traits with the most negative effect on gross emissions per animal in beef are typically growth rate and liveweight (milk yield in dairy). Selection for these traits has driven genetic gain in production efficiency and profitability. To this end, an EI philosophy (as opposed to gross emissions) which tends to favour rather than penalise these traits may in some cases lead to better long-term outcomes (Amer et al. 2017). Conversely, (i.e. for penalising traits with high emissions) appropriate modelling should show that a shift in selection emphasis away from genetic gain in growth rate traits could fit more closely with reductions in beef system intensity, an approach more appropriate to achieve lower gross emissions. With less intensive systems, genetic traits that target cost savings required to offset reduced revenue can increase in relative value to maintain economic viability (Amer, 2022). As previously mentioned, current selection objectives are probably having a favourable impact on beef EI and with more cognizance of carbon costs in the objective, the rate of EI improvement can increase. However, and outside of the control of genetic improvement, if EI is improving, gross system emissions may still increase from the production system if cow numbers increase. If cow numbers remain the same, improved production efficiency resulting in increased output will improve EI and likely gross emissions but to a lesser extent. Larger GHG mitigation can be achieved if increases in production efficiency manifest as product produced remaining stable with a reduced cow herd.

National Focus

North American production systems on average produce beef with a relatively low carbon footprint. This is due to both good genetics and management practices. To focus on reducing gross emissions of the herd (per farm, per county, per state, nationally etc.), production will inevitably have to decrease (barring an extremely steep improvement in EI). This would have detrimental consequences on the global beef carbon footprint as beef produced in other less efficient countries would replace the void in market supply left from reduced North American production. There is potential leakage of emissions to less efficient competing industries when policies targeting emissions result in reduced domestic industry output (Amer, 2022)

Summary

Breeding and genetics can play a significant role in addressing the global challenges facing livestock sustainability. Methodological frameworks exist and continue to evolve for deriving gross emission and EI weighting factors to create carbon influenced selection objectives. Approaches and modifications to current objectives for a gross emission or EI end goal will differ. Generally, current genetic trends in growth and cost saving traits have contributed, and will continue to contribute to substantial improvements in EI. Carbon price has a large impact on predicted responses to selection and relative emphasis on carbon relevant traits in economic selection indexes. Traits like age at slaughter and methane yield carry a lot of potential when it comes to selecting for a reduced carbon footprint.

Other traits such as liveweight, calving interval, feed efficiency, cow longevity and age at first calving are all examples of criteria that indirectly impact GHG from the system and would tend to feature in a carbon (sub-)index. Focussing on EI would be preferable in zones where the beef carbon footprint is better than average. A focus on gross emissions reduction can reduce overall beef production only with that vacated demand to be met by beef product from less efficient production systems, thus having a negative effect on the global beef carbon footprint. When considering breeding strategies, policy mechanisms and farmer adoption and behaviour will be critical to achieving environmentally conscious genetic progress. Supporting infrastructure enabling performance recording, data collation and genetic improvement can also serve as a good platform to build more elaborate GHG assessment systems.

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