Consequences of using different economic selection index methods on greenhouse gas emissions in beef cattle

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Abstract

The impacts of using partial (sub) indexes on expected greenhouse gas emissions (GHG) from a self-replacing cow herd producing 120-day grain-finished progeny is compared to selection with a full self-replacing BreedObject index. Sub-indexes only containing post-weaning traits of the slaughter progeny (terminal) and a maternal sub-index were developed using BreedObject. The terminal sub-index is expected to increase mature cow weight (MCW) and milk, resulting in increases in GHG emissions. In contrast, the full self-replacing index is expected to produce slight reductions in MCW and negligible change in milk, which results in decreases in GHG emissions of the cow herd and young animal at pasture. The maternal sub-index is expected to result in larger GHG emission reductions due to larger decreases in MCW as well as negligible change in milk. When constructing partial indexes, the implications on GHG emissions of the cow herd and progeny need to be carefully considered.

Introduction

Pressure is increasing to reduce greenhouse gas (GHG) emissions due to societal concerns about climate change. In livestock, attention is particularly focused on beef cattle because of the relatively large contribution made by enteric methane (Edenhofer *et al.* 2014). Blaxter and Clapperton (1965) showed the association between feed intake (FI) and GHG emissions, which Walmsley *et al.* (2019) used to show upward trends in GHG emissions due to increased FI from productivity gains in the absence of feed efficiency improvements (Walmsley *et al.* 2017). Barwick *et al.* (2019) demonstrated GHG emissions improvements could be made using full production system index selection when feed is appropriately costed, while still increasing net returns. Dividing the breeding objective into sub groupings (sub-indexes) has been proposed as a means of aiding adoption of genetic improvement (Dekkers and Gibson 1998; Wilmink 1996). However, using sub-indexes may not result in optimal selection (Dekkers and Gibson 1998; Barwick & Henzell 2005). The utility of any index is a function of its representation of the production system it is applied in. This has important implications for addressing GHG emissions given the cow herd accounts for the majority of feed-related costs (Walmsley *et al.* 2018). This study examines the impact the use of sub-indexes could have on GHG emissions compared to using a full production system (self-replacing) index.

Materials & Methods

Breeding objectives. Breeding objectives for net return per cow mated were derived with BreedObject (Barwick & Henzell 2005) following the outline of Schneeberger *et al.* (1992), where EBVs are combined into one aggregate EBV for the breeding objective. The EBVs used were from the December 2021 BREEDPLAN analysis for 636 published Hereford sires. The BreedObject genetic parameters were derived from industry and literature estimates, and relevant for *Bos taurus* breeds in Australia. Parameter details can be requested from the author. Weightings (b) applied to the EBV selection criteria, $\hat{u}$, are derived as:

$$b = \mathbf{G}_{11}^{-1}\mathbf{G}_{12}\mathbf{v} \qquad (1)$$

where $\mathbf{G_{11}}$ and $\mathbf{G_{12}}$ are the genetic variances and covariances among BREEDPLAN EBVs (G11) and between these and the objective traits (G12), respectively, and $\mathbf{v}$ is a vector of trait economic values.

The example production system included a pasture backgrounding period followed by a 120-day feedlot finishing period producing 620 kg *Bos taurus* steers at 21 months of age from a self-replacing cow herd at pasture. Traits in the breeding objective relating to the growing animal were sale liveweight (kg), dressing %, saleable meat %, rump fat depth (mm), marbling score (AUSMEAT scale, 1-12), feedlot entry liveweight (kg), weaning liveweight (direct; kg), residual feed intake-pasture (kg/day), and residual feed-intake feedlot (kg/day) plus cow herd traits; weaning liveweight (maternal; kg), calving ease (direct and maternal; %), mature cow weight (MCW, kg), cow weaning rate (%), and cow condition score at joining (1-15). The general form of the economic value for traits is change (Δ) in returns - Δ FI cost - Δ non-feed management cost. The FI associated with Δ in each objective trait was estimated using the equations described by Freer *et al.* (2007).

Constructing partial indexes. A full self-replacing index (Base), a terminal sub-index (TSub) focused on slaughter progeny and a maternal sub-index (MSub) were constructed using BreedObject. The TSub index only contained traits of the growing animal postweaning in the breeding objective but used the same cost structure as the base index. The MSub index was constructed to show what would be required to counter-balance outcomes from the TSub index. The MSub index used the same cost structure and contained all breeding objective traits but only took account of the maternal contribution to slaughter progeny post-weaning.

Production, feed intake and methane responses. Anticipated responses to selection using the Base and partial indexes were examined by comparing the selection differential in EBVs between the top 10% of sires and the whole published sire list when ranked on index. Estimates of genetic total FI (excluding any period of surplus feed) per sire were derived as presented by Walmsley *et al.* (2017). The breeding objective did not include GHG emissions and residual GHG emissions were not included as EBVs because they are not currently available and their associations with other traits are still under investigation. Methane production was derived using the phenotypic relationships between FI and methane production of Charmley *et al.* (2016) when animals were at pasture, equation 7 of Johnson *et al.* (1993) when animals were in the feedlot, and the recommended global warming constant for methane (28; Edenhofer et al. 2014) for determining kg of CO2-equivalent.

Results

Figure 1 shows calving ease, sale liveweight and cow weaning rate have the highest positive relative economic emphasis, while negative economic emphasis is placed on feed efficiency (reducing RFI is desired), MCW and milk, to reduce feed requirements. Selection differentials in Figure 2 show the Base index is expected to result in slight reductions in MCW and negligible change in milk while allowing improvements in the other production EBVs, such as calving ease, growth, carcass quality and fertility (negative desired). This index is also expected to result in reductions in both FI and GHG emissions of the cow herd (Figure 2b) and the young animal at pasture, but small increases for the young animal in the feedlot. In comparison, the TSub index is expected to increase growth capacity, which is associated with increases in MCW and milk EBVs. The TSub index is also expected to result in negligible change in calving ease, small improvements in fertility and carcass EBVs along with expected increases in both FI and GHG emissions across the production system.

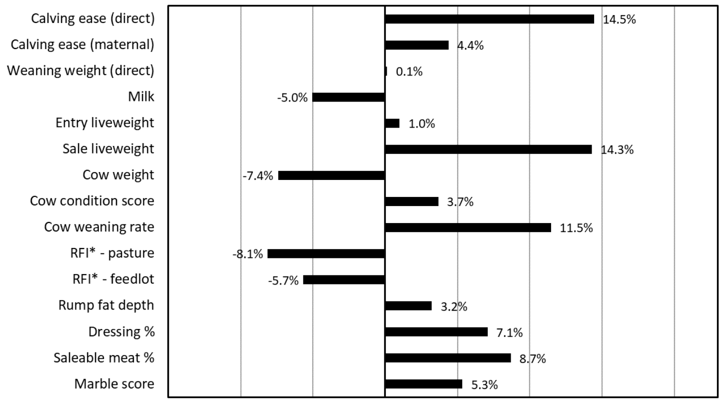

Figure 1. The relative economic emphasis on the breeding objective traits for a self-replacing production system producing 120-day grain-finished steers (Base index).
*RFI is residual feed intake.

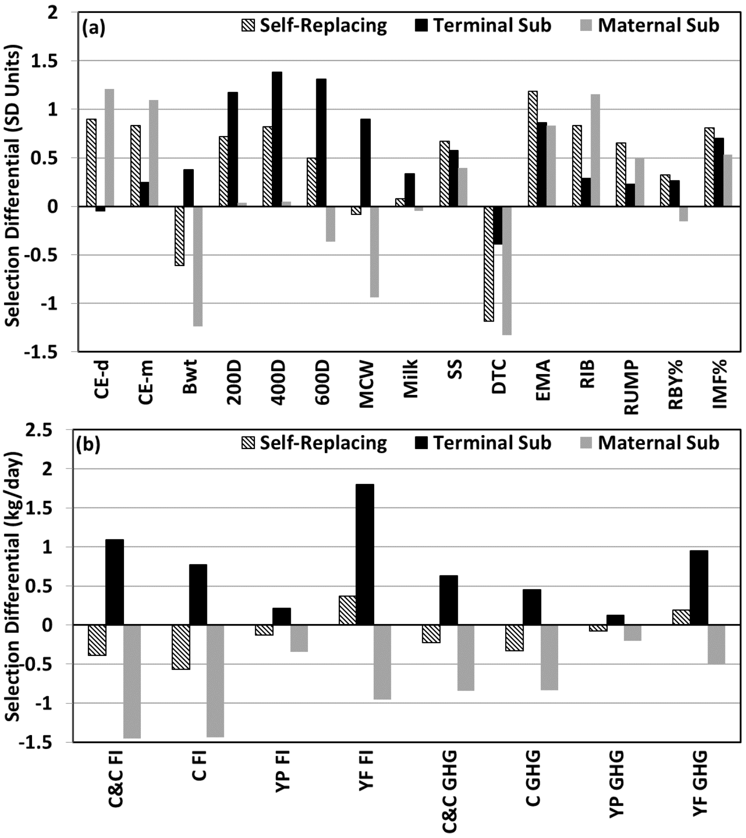

Figure 2. Selection differentials between top 10% and full published Hereford sire list ranked on the self-replacing index (base), the terminal sub-index (TSub) or the maternal sub-index (M-Sub) for (a) the BREEDPLAN EBVs and (b) estimated daily feed intake and greenhouse gas emissions.[#]

[#]Traits: CE-d: calving ease-direct, CE-m: calving ease-maternal, Bwt: birth weight, 200D: 200-day weight, 400D: 400-day weight, 600D: 600-day weight, MCW: mature cow weight, Milk: 200-day maternal weight, SS: scrotal size, DTC: days-to-calving, EMA: eye muscle area, RIB: rib fat depth, RUMP: rump fat depth, RBY%: retail beef yield percentage, IMF%: intramuscular fat percentage, C&C: cow and calf at pasture, C: only cow at pasture, YP: young animal at pasture, YF: young animal in feedlot, FI: feed intake and GHG: GHG emissions.

The selection differentials in Figure 2 also show the MSub index is expected to reduce MCW which is expected to lead to reductions in FI and GHG emissions in the cow herd. The MSub index is also expected to improve fertility, calving ease and carcass traits, other than retail beef yield. However, growth potential is expected to decrease particularly for 600-day weight which also results in reductions in FI and GHG emissions for the young animal.

Discussion

The results highlight if partial indexes intended for the post-weaning segment only were inappropriately applied then they should be expected to result in undesirable increases in FI and subsequently GHG emissions in the cow herd. The development of maternal indexes could be an avenue for partially countering such an outcome, but it comes with the added expense of maintaining two breeding nuclei and potentially compromising gains in production traits like retail beef yield or feedlot growth performance thus negatively impacting feedlot profitability. In contrast, a well-constructed self-replacing index is capable of restricting MCW while allowing other production traits to improve and result in a reduction in expected FI and GHG emissions. When constructing partial indexes, the potential implications on GHG emissions need to be carefully considered, particularly if there is scope for these indexes to be inappropriately used when breeding replacement females.

Acknowledgements

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