LETTER

Reply to Tichenor: Proposed update to beef greenhouse gas footprint is numerically questionable and well within current uncertainty bounds

We thank Tichenor (1) for the attention to our paper (2). In it, we repeatedly stress the need for augmented and more refined data, and it is in this spirit we welcome Tichenor's letter. However, as shown in Fig. 1, Tichenor's approach, based on analyzing a single farm in Sweden (3), yields beef greenhouse gas (GHG) emissions that are within 9% of ours. This discrepancy—less than half of our stated 20% uncertainty and hardly Tichenor's claim for "dramatic overestimation"— actually substantiates the robustness of our analysis.

Multiple viable methodologies for distributing GHG burdens among beef and dairy exist, including physical-, economic-, and nutrition-based ones, each yielding unique overall burdens (4, 5). To date, none of these methods has emerged as the clear universal choice. Tichenor's approach to partitioning GHG emissions among dairy beef is in principle a viable alternative to ours. It represents a tradeoff: added fidelity, but—with less data sources to rely on at this time—larger uncertainty. Either way, as we show below, the two methods yield results that are mutually well within our stated uncertainty.

In Fig. 1 we schematically depict three alternative approaches to the dairy–beef GHG partitioning problem. The left column represents our simplified, yet robust, methodology. We obtain total GHG burdens (red rectangle) by multiplying national loss-adjusted consumed beef (bar height; kilograms) by beef's GHG intensity (bar width; kg CO_{2eq}/kg edible beef). Dairy's beef contributions arise from culled dairy and steers and nonreplacement dairy calves fed for beef including market steers and heifers and veal calves, each characterized by a distinct lifecycle and GHG intensity. Tichenor relies on a single GHG intensity for all dairy beef contributions, obtained from a single unpublished study (3) examining a single farm in the markedly distinct dairy–beef system of Sweden (Fig. 1, *Right*).

Fig. 1, *Center*, depicts the ideal approach in which each subcategory of dairy meat mentioned above is characterized by its relevant GHG intensity. Summing the subcategories' individual emissions, each reflecting the appropriate GHG intensity, represents beef's total GHG emissions more accurately. Because dairy market steers and heifers (approximately half of dairy's contribution to beef) spend only the preweaning few weeks to at most 2 mo in the dairy system, subsequently joining the beef herd for the bulk of their life span, their GHG intensity is some combination of dairy's and beef's intensity, heavily skewed toward the latter.

Ideally, these limitations would spur future data collection efforts. We find Tichenor's suggested method conceptually helpful, but practically and quantitatively premature, as it relies on a single GHG intensity value, proposed by one unpublished study of one single farm in the Swedish dairy system (3).

Using Tichenor's approach, total beef GHG emissions decrease by 9%, well below our fully documented uncertainty estimate. Tichenor's minor but nonnegligible proposed correction thus leaves our published results (2) qualitatively unchanged.

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The authors declare no conflict of interest.

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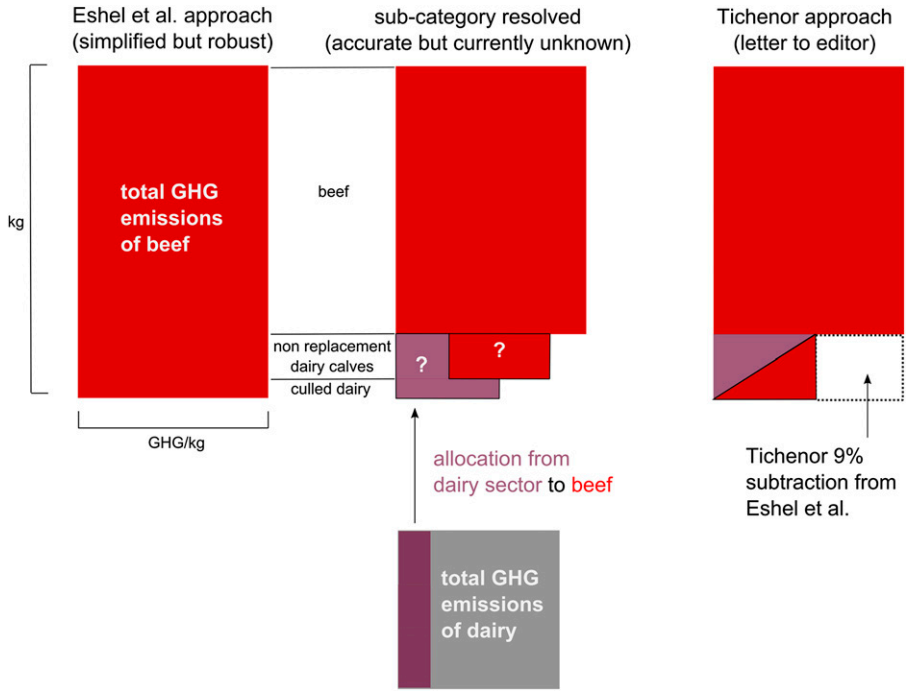

Fig. 1. A schematic representation of three approaches to calculate beef's GHG burdens. Rectangle heights represent loss adjusted consumed beef and dairy masses, whereas bar widths represent GHG intensity in $kgCO_{2eq}$ per edible kilogram. The areas thus represent total GHG burdens of beef (red) and dairy (gray). (*Left*) Our original approach (2), in which loss adjusted consumed beef mass is multiplied by beef's GHG intensity. (*Right*) Tichenor's proposed alternative (1), in which dairy's beef contribution (≈17% of total beef) is allocated based on a single GHG per edible kilogram coefficient equal to about half of the beef value, thus leading to a 9% reduction (18,520/204,062, in units of 10^6 kg $CO_{2,e}$/*y*). (*Center*) Ideal correction in which each subcategory is characterized by a numerically robust GHG intensity, the sum of which is beef's accurate total GHG burdens. Note that diary beef has associated GHG emitted both in the dairy sector and the beef sector (feeding of nonreplacement calves) and is thus marked as partially purple and partially red.