E. Lai, E., Cleveland, M. (2026) A LCA for male-skew genetics: Harnessing sex determination as an environmental mitigation strategy in beef-on-dairy, *Proceedings 13th World Congress on Genetics Applied to Livestock Production*
23838: https://doi.org/10.31274/wcgalp.23838 ©2026 Lai, et al. CC BY-NC-ND

A LCA for male-skew genetics: Harnessing sex determination as an environmental mitigation strategy in beef-on-dairy

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Introduction

Beef-on-dairy (BxD) animals are the result of increasing the value of surplus, non-replacement calves at the dairy: breeding a dairy cow to beef semen creates a higher value calf whose beef genetics predispose the animal to grow more efficiently and acquire favorable carcass characteristics in terminal beef systems compared to straightbred dairy steers. The beef genetics used in BxD systems can be further refined to optimize the BxD animal for terminal beef production in two ways: using higher indexing genetics from breeding programs designed for BxD production and, more recently, using male-skew genetics. Both approaches are expected to improve the efficiency of BxD production and in turn lower the environmental footprint. Previous work has demonstrated that genetic improvement via the ABS NuEra Genetics breeding program reduces the climate change impact of BxD animals by 4.6-8.8% relative to industry average genetics in US and UK populations, with similar reductions in other impact categories (Lai et al., 2025; Lai and Cleveland, 2025). Male skew semen is created by deactivating X chromosome-carrying sperm to maximize the chance that the remaining Y chromosome-carrying sperm cells will fertilize the egg, biasing the sex of the calf to male. Male-skew genetics has long been conjectured as a promising method to capitalize on the faster growth and feed efficiency gains of steers compared to heifers (Hohenboken, 1999), provided that the BxD calf is valued higher than a purebred dairy calf (De Vries et al., 2008). Only recently has male-sexing technology advanced sufficiently to support commercial use, which comprised ~0.5% of calvings in US dairy herds in 2023 (Basiel et al., 2025). Pre-selecting the more efficient sex optimizes resource usage by reducing wastage from creating the less efficient sex, which decreases the environmental footprint of the production system (Quelhas et al., 2023). Although the environmental benefits from using higher indexing NuEra genetics in BxD systems have been previously quantified, the additional effect on environmental footprint from using male-skew genetics has not been reported. Accordingly, the objective was to quantify the change in environmental footprint due to using male-skew genetics relative to conventional genetics at varying levels of genetic merit.

Materials & Methods

An ISO 14040 and 14044-conformant life cycle assessment (LCA) model previously described (Lai et al., 2025; Lai & Cleveland, 2025) was used to calculate the environmental footprint of conventional (non-sexed) and male-skew BxD progeny in three different systems: a US system focused on faster growth and marbling (US), a UK system focused on producing high quality carcasses (UK-HQ), and a UK system focused on faster growth and higher yield (UK-HY). The LCA system boundary encompassed conception to first processing at harvest and included the dairy at which the BxD calf was conceived, rearer, finisher, and abattoir. Unlike previous work comparing the environmental footprint of NuEra-sired and industry average BxD animals (Lai et al., 2025; Lai and Cleveland, 2025), only NuEra-sired animals were included in this study to evaluate the additional effect of male-skew genetics. NuEra-sired animals were progeny of bulls from the NuEra Genetics program, a proprietary breeding program creating differentiated genetics that optimize terminal beef production from BxD and beef-on-beef animals.

Progeny types. Progeny were grouped by genetic merit level and service sire semen type. Within each population, progeny were assigned to a genetic level based on sire NuEra Profit Index (NPI) values. NPI is a proprietary selection index designed to maximize lifetime profitability of terminal beef animals by optimizing growth, feed efficiency, and carcass characteristics. Two genetic levels were considered: average and elite, respectively corresponding to progeny of NuEra sires falling in the third and fifth quintile of genetic merit measured using the NuEra Profit Index. Progeny were grouped into genetic merit levels based on sire NPI values. Within the average and elite genetic merit levels, environmental footprints were calculated for progeny sired by either conventional or male-skew semen.

Phenotypes used as LCA inputs. Phenotypes were collected in commercial settings from birth to harvest of BxD animals (UK-HQ N=10,214, UK-HY N=3,132, and US N=3,185). IACUC approval was not required as the phenotypes used in this study were repurposed from historic data. Progeny phenotypes included in and out weights and dates for each growing phase (dairy, rearer, and finisher), which were used to calculate the days and average daily gain (ADG) at each growing phase; individual dry matter intake (DMI) at the finishing phase for US and UK-HY; and carcass weight. Phenotypes were adjusted using linear models in R to correct for the effects from contemporary groups, dam breed (US only, as all dams were Holstein in the UK populations), age (for out weight and DMI), and in weight (for days at the growing phase or feeding trial for DMI). Previous work (Lai et al., 2025; Lai and Cleveland, 2025) indicated that the majority (>60%) of the environmental footprint resulted from finishing and that days, ADG and DMI (all three at finishing) were the most influential parameters. These were defined as key performance indicators (KPIs) for the analysis and, accordingly, were the only input parameters for the LCA that varied among each of the progeny types. For conventional genetics, KPI phenotypes were averaged across sex within each sire genetic merit level, and for male-skew genetics, KPI phenotypes were averaged within each sex within each sire genetic merit level. All other parameters from other growing phases were held constant across the progeny types such that resulting differences in environmental footprint reflected the influence of genetic merit at the finishing phase.

Impact assessment. The Product Environmental Footprint 3.1 method for LCIA (European Commission, 2021) was performed for conventional genetics, males, and females for average and elite genetics within each of the three populations. Impact values were calculated and characterized for the 16 damage categories defined in the methodology, of which relevant damage categories were defined as those that contributed to the top 80% of overall impact when normalized and weighted. To calculate the impact for male skew genetics, a conservative 90% male skew was assumed per the minimum product specification, and the impact for male skew was calculated as a weighted average of 90% of the impact from steers and 10% from heifers for each damage category.

Results & Discussion

Male-skew genetics provide a secondary method of tailoring the genetics of BxD animals to optimize terminal performance that builds on selecting higher-indexing sires. Performance gains from genetically replacing heifers with steers translated to a lower environmental footprint from male skew-sired animals relative to conventional semen-sired animals that was additive to the reduction from using higher indexing genetics.

Relevant damage categories. The same damage categories were identified as relevant contributors to environmental footprint of male skew-sired BxD animals as those previously

identified for conventional semen-sired animals (Lai et al., 2025; Lai and Cleveland, 2025). Specifically, climate change, particulate matter, acidification, and terrestrial eutrophication were identified as top damage categories contributing to the environmental footprint for male skew-sired animals in all three populations. In addition to these shared categories, marine eutrophication was a top contributor to the environmental footprint for the UK-HQ and UK-HY male skew-sired animals, land use and fossil fuel resource use were top contributors for the UK-HY male skew-sired animals, and freshwater ecotoxicity and water use were top contributors for the US male skew-sired animals.

Contribution analysis. For all three populations, the top processes contributing to the relevant damage categories previously identified for animals sired by conventional semen were the same processes identified as top contributors for male skew sired animals: feed production, manure management, and, for climate change only, enteric fermentation (Figure 1). The contribution from these three top processes to each damage category was lower for the male-skew sired animals compared to conventional semen-sired animals of the same genetic level. For climate change, male-skew sired animals had a 1.4-3.9% lower emission intensity from each of these three processes compared to their conventional counterparts in the same genetic level, driving the 1.2-3.8% (0.23-0.30 kg CO_2e/kg carcass weight) reduction across genetic levels and populations when combined with impacts from other processes. For particulate matter formation, acidification, and terrestrial eutrophication, male-skew sired animals had a 1.1-5.4% lower impact from feed production and manure management compared to their conventional counterparts, underpinning similar total reductions (1.1-4.8%).

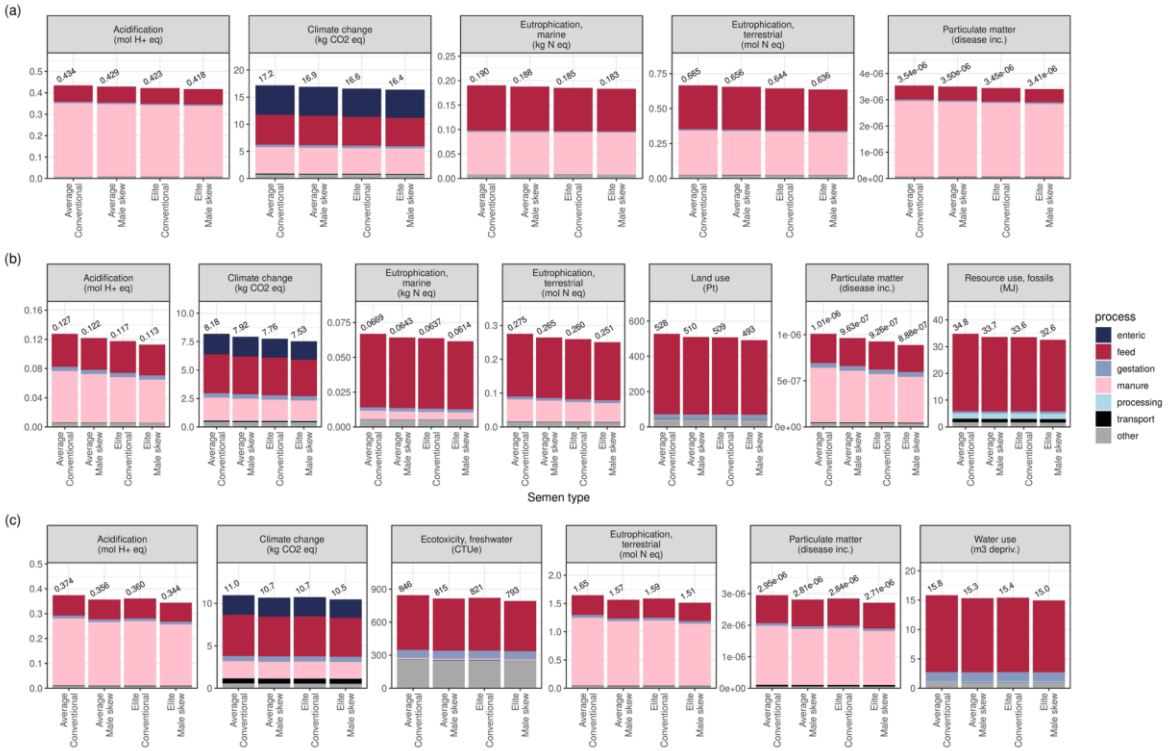

Figure 1. Process contribution to and total impact per kg of carcass weight (bar labels) from each relevant damage category of the environmental footprint for beef-on-dairy animals sired by conventional or male-skew semen with either average or elite genetic merit in the (a) UK high quality, (b) UK high yield, and (c) US populations.

Effect of male skew on top contributing processes. In all three populations, steers had greater ADG compared to heifers of the same genetic level, which enabled steers to reach harvest

weight in fewer days than heifers. For the US and UK-HY populations, steers consumed more feed per day than heifers of the same genetic level; however, the increase in footprint due to higher DMI for steers was offset by the fewer days to harvest, such that the total amount of feed consumed over the finishing phase was less in steers compared to heifers of the same genetic level. In the UK-HQ population, no feeding trial data was available, so DMI was assumed to be the same between steers and heifers. Due to this limitation, in the UK-HQ population, the lower environmental footprint of steers compared to heifers was driven solely by the faster ADG in steers leading to fewer days to harvest and did not account for the likely higher feed intake of steers, which would offset the environmental benefits from faster growth. The performance gains from male-skew sired animals compared to their conventional counterparts manifested as lower impact from the top contributing processes to the relevant damage categories: lower feed intake over the finishing period from male skew-sired animals decreased the environmental footprint from feed production, translated to less manure produced, and, for climate change, reduced methane emissions from enteric fermentation. The environmental impact reduction as a result of switching from conventional to male skew genetics was approximately half of (UK-HQ), similar to (UK-HY), or higher than (US) the reduction from switching from average to elite conventional genetics. A stronger male skew (>90%) would result in further estimated environmental benefits: for each additional 1% skew, the environmental footprint would decrease an additional 0.02-0.14% across impact categories.

Conclusions

Although the performance gains of steers relative to heifers in terminal beef production have been extensively documented (e.g., Ray et al., 1969), the intentional biasing of the calf crop to steers and the resulting environmental benefits are relatively new applications. Here we present the first environmental footprint estimate for male-skew genetics in BxD systems modeled using an LCA framework and contextualize the results with the footprint of conventional genetics at varying levels of genetic merit. Under the assumptions used in the LCA, the environmental footprint reduction from using male-skew genetics was similar across different genetic levels within each population, demonstrating that male-skew genetics is an effective mitigation method at any genetic level, and that its benefits are additive to the reduction from using higher indexing genetics. Male-skew genetics provides an additional mitigation strategy that is additive to using higher indexing genetics to further reduce environmental footprint while simultaneously improving the profitability of the producer, thereby advancing the sustainability of the BxD production system.

References

Basiel, B. L., Graham, J. R., and VanRaden, P. M. (2025) J Dairy Sci. 108(9):9901-9914. doi.org/10.3168/jds.2025-26600

De Vries, A., Overton, M., Fetrow, J., *et al*. (2008) J Dairy Sci, 91(2):847–856. doi.org/10.3168/jds.2007-0536

European Commission. (2021) Commission Recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. Available at: https://www.consilium.europa.eu/media/40928/st12791-en19.pdf, visited on: 19-06-2025.

Hohenboken, W. D. (1999) Theriogenology, 8(52):1421–1433. doi.org/10.1016/s0093-691x(99)00227-7

Lai, E., Brown, A., and Cleveland, M. A. (2025) Proc. of BSAS Conference, Galway, Ireland. doi.org/10.1016/J.ANSCIP.2025.04.072

Lai, E., and Cleveland, M. A. (2025) Proc. of ADSA Annual Meeting, Louisville, KY, USA. https://www.adsa.org/Portals/0/SiteContent/Docs/Meetings/2025ADSA/Abstracts_BOOK_2025_20250624-1249.pdf

Quelhas, J., Pinto-Pinho, P., Lopes, G., *et al*. (2023) Front Vet Sci, 10:1181659. doi.org/10.3389/fvets.2023.1181659

Ray, D. E., Hale, W. H., and Marchello, J. A. (1969) J Anim Sci, 29(3):490–495. doi.org/10.2527/JAS1969.293490X