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Derivation of economic values for an intensive beef-on-dairy crossbred system using a bio-economic model

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Introduction

In Denmark, beef-on-dairy crossbreeding where lower-merit dairy females are inseminated with beef semen from genetically superior bulls, has gained traction as crossbred calves have higher economic value due to improvements in growth rates, carcass quality and feed conversion. As this production expands, it intersects with national climate policy priorities. A CO_2 taxation scheme was formulated in the Green Tripartite framework which was introduced to incentivize reductions in greenhouse gas emissions from agriculture. The scheme will be implemented to account for methane and CO_2 emissions from cattle in the future with tax rates at 16.08 €/ton CO_2-equivalent (CO_2-e) in 2030 and 40.19 €/ton CO_2-e in 2035 (Tripartite, 2024). These represent the average effective tax rate after the 60 % base deduction; the marginal tax on an additional 1 kg CO_2-e is the full tax rate. This policy underscores the need for sustainable breeding goals in beef-on-dairy systems and hence quantifying the economic values (EV) of sustainability and health traits, such as methane (CH_4) emissions, feed efficiency and diseases. However, complex interactions between growth, health, carcass performance, and management practices make this challenging, highlighting the need for a bio-economic model for setting the breeding goal.

Globally, bio-economic models are well established for suckler (Wolfová *et al*., 2005) and dairy cow systems (Nielsen *et al*., 2006). To our best knowledge, the only published bio-economic model for beef-on-dairy production was developed in the Irish national breeding program under Irish circumstances (Berry *et al*., 2019). However, both production and pricing systems differ greatly between Denmark and Ireland.

Hence, the aim of this study is to estimate EV of growth, carcass value, feed efficiency, CH_4 emissions, health and survival traits using a bio-economic model tailored for intensive production of beef-on-dairy slaughter calves in Denmark.

Materials & Methods

The bio-economic model focused solely on the fattening and slaughter system for beef-on-dairy calves. 500 calves from Danish Blue sires mated to Holstein dams (60% male) were sold at 31 days of age (~60 kg), reflecting common practice in Danish dairy systems where calves are transferred to fattening units within the first month. Calves were reared until slaughter at 300 days. The dairy herd was not modelled in this study and therefore all calves entering the system were treated as a terminal cohort. In the period from 31 to 72 days the calves received milk powder (0.6 kg/day) and a concentrate mixture (1.5 kg/day). The calves then transitioned to higher level of concentrates (5.5 kg/day) and a ration of 0.5 kg/day of roughage until slaughter. The model estimated profit at herd level and included 10 traits. The level of the traits and the genetic standard deviations of EUROP conformation score, fat score, average daily gain (ADG), dressing percentage (DP), diarrhea, pneumonia, claw disorders and youngstock survival (YSS) were determined from real data received from the Danish cattle database from 2000 to 2024.

Feed efficiency and methane (CH_4) production data was obtained from the Future Beef Cross research project, where data were collected from five beef-on-dairy herds, comprising 8,169 Blue-sired calves, using automated sniffer systems to record individual feed intake and CH_4 emission (Johansen *et al*., 2025).

The bio-economic model used in this study estimated herd-level profit, defined as revenue minus costs for an average beef-on-dairy fattening herd in the intensive system, and was calculated as:

$$\pi_{farm} = ((N_{animals} * (r_s + \Delta YSS)) * C_v) - C_F - C_B - \boldsymbol{c_A} - C_m \quad (1)$$

Revenues were calculated from the number of slaughtered calves multiplied by the carcass value, C_v. The revenues included the number of animals sold to the fattening herd, $N_{animals}$, multiplied by the baseline survival rate of 96%, r_s. ΔYSS was the improved survival rate when increasing the trait level, resulting in a survival rate of 97%. YSS was modelled using a Poisson model for daily mortality from day 31 to 300, where survival probability was calculated as $S(t_{31}, t_{300}) = \prod_{d=t_{31}}^{t_{300}} e^{-\lambda d}$, where λ was the daily risk of death, d (Janssen *et al*., 2017). The carcass value depended on the carcass weight and slaughter price. The carcass weight was obtained as the product of live weight (average of 450 kg) with DP that had a mean of 54%. Live weight was modelled using a Gompertz growth curve assuming a target age at slaughter of 300 days and live weight could vary as a result of changes in ADG (1.23 kg/day on average). Average carcass selling price was 6 €/kg carcass based on average EUROP conformation and fat score. EUROP conformation score and fat score were measured on carcass in a grading scale system (1-15 points), with mean values of 6.79 and 2.47, respectively. Payment or penalty values associated with each score class can be found in the Nordic BeefxDairy Index that was updated in 2024 (Pedersen *et al*., 2024).

Production costs included fixed costs at herd level (C_F), a fixed cost of buying the slaughter calves (C_B) from the dairy herd (175 €/calf), variable costs per animal (C_A) and costs associated with calf mortality (C_m). Fixed costs were 0.28 €/day/calf for labour, 0.33 €/day for capital, 0.24 €/day for capacity, with additional per-calf costs of 30.5 € for transportation and 3.7 € for advisory services.C_A were expressed per animal per day and summed over the whole fattening period:

$$\boldsymbol{c_A} = \sum_{t=31}^{T} [\mathbf{DMI}(t) * C_{\mathrm{DMI}} + \Delta \mathrm{RFI}] + \mathbf{DI} * C_{\mathrm{DI}} - \Delta \mathrm{DI} + \mathbf{CH_4} * C_{\mathrm{CO2}} - \Delta \mathrm{CH_4}] \quad (2)$$

Feed costs depended on daily dry matter intake (DMI) multiplied by the feed cost (C_{DMI}, expressed per kg DMI), and were modulated by feed saved through the improvement of feed efficiency that was modelled as RFI (ΔRFI). RFI was estimated as the difference between observed and predicted DMI (Berry & Crowley, 2013). Predicted DMI was estimated with the following equation obtained by multiple linear regression of DMI on ADG and metabolic live weight (MBW): $\mathrm{DMI}_i = 0.83 + 0.395 * \mathrm{ADG}_i + 0.071 * \mathrm{MBW}_i$. Feed costs associated with increased live weight were calculated using observed and predicted DMI to estimate the feed required for higher ADG.

Cost of diseases was calculated as the disease incidences DI (Average lifetime disease incidences were 11.6 % for diarrhea, 36.9 % for pneumonia, and 4.8 % for claw disorders) times the cost associated with treatment of the animal including medicine and personal time (14.47 €, 10.32 € and 10.32 €/treatment respectively). ΔDI was estimated by reducing disease incidence, which lowered total treatment costs. The average CH_4 emissions was derived from real data with a mean production of 189 L/day/calf (Johansen *et al*., 2025). It was assumed that the CH_4 production/day was the same through the fattening period. Finally, costs associated with the dead calves (C_m) covered the labour and the cost of disposal of dead calves being 33.41 €/dead calf in total. Marginal EV were estimated for a 0.01-unit improvement of one trait per animal while keeping the other traits constant calculated as:

$$\mathrm{EV}_{i,\mathrm{animal}} = \left(\frac{\pi_{\mathrm{improved},i} - \pi_{\mathrm{baseline}}}{N}\right) \quad (3)$$

Where $\pi_{improved}$ was the herd level profit after increasing trait *i* by 0.01-unit, $\pi_{baseline}$ was the baseline herd profit with no trait improvement and N was the number of animals alive at slaughter. Standardized EV were calculated from marginal EV as: $EV_{i,\sigma_A} = \frac{EV_{i,animal}}{0.01} * \sigma_{A,i}$ where the marginal EV per animal, $EV_{i,animal}$, was divided by the improvement of trait *i,* and multiplied by the genetic standard deviation of trait *i,* σ_A.

Trait-specific improvements were applied according to their biological characteristics: YSS via survival probability over the fattening period, EUROP conformation, fat score, and DP by shifting their mean. Diarrhea, pneumonia, and foot rot by reducing treatments. RFI as lower feed intake, CH_4 as reduced daily production and ADG as increased daily gain with a fixed slaughter age, affecting live weight and feed intake throughout fattening.

Results & Discussion

Table 1 summarizes the marginal EV and standardized EV obtained from the bio-economic model for different traits along with their genetic standard deviations.

Table 1. Units of the traits improved, Marginal economic values (EV), genetic standard deviations ($\boldsymbol{\sigma_A}$) and standardized EV of the traits modelled.

Traits	Units	Marginal EV (€/unit)	σ_A	€/σ_A
EUROP score	Points	0.02	0.49	1.17
Fat score	Points	0.07	0.23	1.59
Average daily gain	Kg/day	7.22	0.03	19.12
Dressing percentage	%	27.00	0.01	31.09
Young stock survival	%	9.63	0.06	54.39
Diarrhea	%	0.15	0.06	0.84
Pneumonia	%	0.10	0.25	2.58
Claw disorder	%	0.10	0.02	0.22
Residual feed intake	Kg/day	1.56	0.34	53.55
Methane production	Kg/day	0.45	0.31	14.31

In our study RFI had the highest standardized EV of 53.55 €/σ_A. Berry *et al*. (2019) found using a bio-economic model for a beef-on-dairy system, an EV of feed intake of −35.27 €, which was the largest estimated standardized EV among the traits. Both traits contribute to increased profit by lowering feed costs and have high EV because feed costs represent the largest production expense.

In our study, ADG and DP had much higher EV (19.12 €/σ_A and 31.09 €/σ_A) than EUROP conformation score and fat score (1.17 €/σ_A and 1.59 €/σ_A respectively). These low EV for carcass conformation and fatness resulted from most calves being near optimum. In production systems where animals are generally less lean and subject to higher bonus for fat and conformation, the EV of these traits could increase substantially. In contrast, Berry *et al*., (2019) estimated relatively high EV for conformation and fat scores (17.58 € and −8.24 €, respectively). The negative EV of fat score reflects the fact that increases in fat tend to reduce the proportion of

high-value carcass cuts, leading to a net decrease in revenue. The economic importance of fat score may also rise in the future in Denmark if production shifts from intensive systems toward longer, more grass-based rearing due to the new climate deal from the Green tripartite that requires more land for grazing. DP entails no additional costs to improve, and the high carcass price yields a high EV (27.00 €/σ_A); this trait was not included in Berry *et al*. (2019). Beef prices vary weekly and strongly influence revenue. The model used the current market price of 6 €/kg carcass, which is quite high compared to previous years. Indeed, beef prices for standard quality have risen by ~2 €/kg over the last two years, adding uncertainty to revenue estimates.
YSS had a high EV of 54.39 €/σ_A reflecting the increased revenue from more calves surviving until slaughter. Because calves in the fattening unit have higher feed intake than younger calves in dairy herds, the economic loss associated with mortality is greater, resulting in a higher economic value of survival in the fattening unit (Davis *et al*., 2020). To our knowledge, diarrhea, pneumonia, and claw disorders are only recorded in Danish beef-on-dairy systems. Their EV are considerably low due to relatively low treatment costs, but their high prevalence has important implications for animal welfare and ethical concerns of the production. Disease recordings might be biased by the occurrence of group treatments that are allowed in Denmark, which may lead to overestimation of true disease prevalence. Our model incorporates RFI and CH_4 emissions (53.55 €/σ_A and 14.31 €/σ_A): traits that are rarely recorded in either suckler beef or beef-on-dairy systems. Reducing CH_4 emissions is expected to become increasingly relevant due to emerging CO_2 taxation schemes in Denmark; however, the current tax represents a relatively small proportion of production costs, resulting in a low EV.

Conclusions

We developed a bio-economic model for estimating EV of traits for beef-on-dairy calves fattened in an intensive production system under Danish circumstances. Production traits such as ADG, DP and RFI exhibit substantially higher EV than health traits and CH_4 production. In particular, the inclusion of RFI, with an EV of 53.55 €/σ_A, is crucial for improving the profitability through reduced feed costs. The inclusion of YSS, with the highest EV of 54.39 €/σ_A, enhances survival rates and overall profitability, while also addressing animal welfare considerations and broader societal concerns related to sustainable livestock production. Although the EV of CH_4 production is low, including it in the breeding goal contributes to improved environmental sustainability. Predicting selection responses on CH_4 would be necessary to quantify its overall effect on sustainability.

References

Berry, D., & Crowley, J. (2013). J. Anim. Sci., 91(4), 1594-1613. https://doi.org/10.2527/jas.2012-5862

Berry, D. P., Amer, P. R., Evans, R. D., *et al*. (2019). J. Dairy. Sci. , 102(11), 10056-10072. https://doi.org/https://doi.org/10.3168/jds.2019-16912

Davis, R., Norberg, E., and Fogh, A. (2020). Anim., 14(3), 445-451. https://doi.org/10.1017/S1751731119002386

Janssen, K., Berentsen, P., Besson, M., *et al*. (2017). Genet. Sel. Evol., 49(1), 5. https://doi.org/10.1186/s12711-016-0278-x

Johansen, K. K., Kargo, M., Christensen, O. F., *et al*. (2025). Anim., 101478. https://doi.org/10.1016/j.animal.2025.101478

Nielsen, H. M., Groen, A., Østergaard, S., *et al*. (2006). Acta Agri. Scand. A Anim. Sci., 56(1), 16-32. https://doi.org/10.1080/09064700600836786

Pedersen, J., Aamand, G. P., Fikse, F., *et al*. (2024). https://nordicebv.info/nbdi/

Tripartite, M. f. G. (2024). https://regeringen.dk/aktuelt/publikationer-og-aftaletekster/aftale-om-et-groent-danmark/

Wolfová, M., Wolf, J., Přibyl, J., *et al*. (2005). Livest. Prod. Sci., 95, 201-215. https://doi.org/10.1016/j.livprodsci.2004.12.018