

## Trade-offs among grass-based veal production systems along an altitudinal gradient

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Developing grass-based veal production from male dairy calves may offer a low-input and welfare-oriented alternative, particularly in organic systems. While previous studies reported significant univariate differences between farming systems, it remains unclear whether systems differ when all traits are considered jointly, and how trade-offs emerge among production, animal health, environmental, and economic traits. We fattened 72 calves from 90 to 180 days of age in four Swiss grass-based systems: one hay-based indoor system and three pasture-based systems located in lowland, mid-elevation and alpine areas. Plant diversity was monitored repeatedly in pastures throughout the grazing season, and in-vitro methane production was assessed from rumen fluid collected on farms shortly before slaughter. Productivity, meat quality, animal health and carcass price were measured after slaughter. System differences were evaluated using a permutational multivariate analysis of variance (PERMANOVA) followed by linear discriminant analysis (LDA). The PERMANOVA revealed a significant multivariate differentiation among systems ( $p < 0.001$ ,  $R^2 = 0.35$ ). The LDA showed a clear separation between systems (90% correct classification), mainly driven by average daily gain, meat quality traits and blood haemoglobin concentration. Alpine and mid-elevation systems were associated with higher plant diversity and improved animal health, whereas the indoor system showed higher growth performance, lower in-vitro methane production, and more protein-rich and tender meat. Despite these differences, carcass prices were similar between alpine and indoor systems, partially due to seasonal effects. These results highlight distinct trade-offs among grass-based veal production systems in terms of food provision, biodiversity conservation, and climate change mitigation, which should be considered in policy design and large-scale modelling.