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Effects of circular food resource inclusion in diets on ruminant productivity: A mixed-effects meta-regression analysis

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Abstract

Considering their availability (132 kg per capita per year) and relevance to the circular bioeconomy prospects, circular food resources (CFRs) - including surplus crops, food processing by-products, and discarded plant-based materials - have strong potential as ruminant feed. However, evidence remains limited regarding the levels at which CFRs can be included without compromising productivity or whether they provide additional benefits. To address this, we synthesized data from two literature-based datasets on average daily gain (ADG) and milk yield. The compiled dataset comprised 735 animals (cattle, sheep, and goats) across 32 dietary treatments incorporating food leftovers, by-products, and unsold vegetables, alongside 33 treatments based on conventional feedstuffs, under diverse management conditions from 20 global studies. Descriptively, energy-corrected milk (ECM) was higher in diets including CFRs (10.1 ± 3.6 , mean $\pm$ SD) compared to no inclusion (8.24 ± 3.4). Similarly, ADG expressed per kg body weight was slightly higher under CFR inclusion (6.52 ± 4.14 vs. 5.04 ± 4.33 g kg⁻¹ BW day⁻¹). For analytical assessment, CFR inclusion levels were categorised as no (0 %), low (>0–30 %), and high (>30 %). Linear mixed-effects models were applied, with study as a random effect and inclusion level (continuous and categorical) and species as fixed effects. Model results showed that CFR inclusion was positively associated with ECM ($\beta = 0.021$ per %, $p = 0.023$), with no significant species effect. Specifically, low inclusion increased ECM by 1.27 kg TLU⁻¹ day⁻¹ compared to no inclusion ($\beta = 1.27$, SE = 0.36, $t = 3.53$, $p = 0.003$), whereas high inclusion showed no additional benefit ($p = 0.437$). In contrast, CFR inclusion did not significantly affect ADG, irrespective of whether it was modeled as a continuous ($p = 0.757$) or categorical variable ($p > 0.63$). Species, however, significantly influenced ADG, with higher values observed in sheep compared to cattle ($\beta \approx 6.1$, $p < 0.02$). Overall, moderate inclusion of CFRs can enhance milk productivity without compromising growth performance, supporting their role in sustainable ruminant feeding systems.

Keywords: Co-products, Feed sources, Food leftovers, Inclusion level, Sustainability