Characterization of packaging remnants and chemical contaminants in former foodstuff products for animal nutrition

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Former foodstuff products (FFPs) are increasingly recognized as promising circular feed ingredients that contribute to sustainable and resilient livestock production. By valorizing food industry leftovers, FFPs help reduce food waste, improve resource efficiency, and enhance feed self-sufficiency. However, their sustainable use depends not only on their nutritional benefits but also on ensuring their safety, particularly regarding potential contamination from packaging remnants and chemical contaminants. This study aimed to (1) quantify packaging residues and feed-regulated contaminants in FFPs, and (2) explore correlations among packaging materials and contaminants. Fifteen FFP samples were analyzed using Fourier-transform infrared spectroscopy (µ-FTIR) to identify packaging fragments (aluminium, plastic, and polysaccharides such as paperboard), as described in Mazzoleni et al., (2024). Standard analytical methods were used to quantify metallic trace elements (MTEs: Al, As, Cd, Pb) by inductively coupled plasma mass spectrometry (ICP-MS), while persistent organic pollutants (POPs) including polychlorinated biphenyls (PCBs), dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) were analyzed by gas chromatography high resolution or tandem mass spectrometry, respectively, as described in Driesen *et al.*, (2022). Descriptive statistics for each parameter were adressed, as well as Spearman's correlation between contents in packaging fragments and each chemical contaminants using the procedure CORR of the SAS software (9.4). Packaging remnants were frequently detected, with plastic and polysaccharide residues being the most abundant (mean ± standard deviation: 6.5 ± 6.6 and 16.9 ± 11.7 pieces per 60 g of sample, respectively). MTE and POP concentrations showed substantial variability across FFP samples, but all remained below EU regulatory maximum levels and action threesholds for feed. As concentration ranged from 0.01-0.12 mg.kg^{-1} feed at 12% moisture, Pb from 0.03-0.19 mg.kg^{-1}, wheras Cd was detected in only 5 FFPs (0.05-0.06 mg.kg^{-1}). The sum of indicator PCBs ranged from 0.14-0.63 µg.kg^{-1} feed at 12% moisture and the sum toxic-equivalent (TEQ) of PCDD/Fs and dioxin-like PCBs from 0.03-0.11 ng TEQ.kg^{-1} (mid bound). Spearman's correlation revealed significant positive associations between aluminium packaging and hepta- and octa-chlorinated PCDD/F congeners (+0.56 ≤ r ≤ +0.71, P ≤ 0.03) as well as polysaccharide residues with the PCDD/F sum TEQ (+0.77, P = 0.001) and Pb (+0.59, P = 0.03), while plastic residues were also positively associated with Pb (+0.61, P = 0.02). While the detected levels of legacy contaminants do not raise immediate safety concerns, the presence of packaging remnants underscores the need for improved processing strategies to mitigate emerging physical and chemical risks. Future research should focus on refining detection methodologies and addressing safety challenges to fully harness the potential of FFPs as novel feed ingredients for resilient and sustainable livestock production.