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A Nutritional Life Cycle Assessment Framework for Evaluating Food Loss and Waste, and Sidestreams in European Supply Chains

Silvia Zingale[1,*], Manika Rödiger[2], Clara Payro[1,3], Mara Petruzzelli[1], Kim Lindfors[4], Venla Kyttä[4], Hanna Hartikainen[4], Niina Sundin[5] and Thomas Nemecek[1]

[1]*Agroscope, Life Cycle Assessment Research Group, Switzerland*
[2]*Agroscope, Economic Modelling and Policy Analysis Research Group, Switzerland*
[3]*Institute of Environmental Sciences, Leiden University, Netherlands*
[4]*Natural Resources Institute Finland (Luke), Finland*
[5]*Swedish University of Agricultural Sciences, Sweden*

Abstract

Food loss and waste (FLW) is typically quantified in mass and/or dietary energy terms, yet it also represents a loss of essential nutrients that are no longer available to populations, thereby threatening food security. This work, developed within the EU WASTEWISE research project, proposes a comprehensive nutritional life-cycle assessment (nLCA) framework that integrates nutritional losses (NLs) embedded in FLW and sidestreams into environmental impact assessment, addressing a critical methodological gap at the intersection of FLW accounting and LCA research. The framework advances several methodological recommendations: clearer definitions of FLW in nutritional terms, broader system boundaries that explicitly capture sidestreams, the adoption of nutritional adequacy indicators, and careful interpretation of trade-offs between nutritional and environmental outcomes. We applied the framework to three EU food supply chains (bread, pasta and pastry, and tomatoes in Italy, and bovine meat in Switzerland) by coupling detailed Material Flow Analyses (MFAs) with food composition data to quantify NLs for multiple macro- and micronutrients. NLs were expressed in absolute terms, relative to population-weighted Dietary Reference Values (DRVs), and as food group-specific nutritional indicators (Nutrient Rich Food (NRF)-type indices). The NRFs assess nutritional density, and can serve as functional unit in nLCA, enabling the joint optimisation of nutritional and environmental performance. Results revealed substantial cumulative NLs across all three chains. In the tomato chain, combined FLW and pomace sidestream losses contain sufficient vitamin A to cover 87% of the Italian population's daily requirement, with processing identified as the NLs hotspot for 8 of 9 tracked nutrients. In the bread, pasta and pastry chain, milling sidestreams and production-stage grain diversions for non-food uses alone generate losses exceeding the entire Italian population's requirements for dietary fibre, phosphorus, magnesium, thiamine and iron. In the bovine meat chain, offal and blood sidestreams could cover around 27% and 16% of the Swiss population's vitamin B12 and iron requirements respectively, critical nutrients for which dietary inadequacies are documented particularly among women. The contribution of each supply chain stage to NLs was strongly dependent on both the food chain, and the nutrients considered. Nevertheless, across the chains investigated, processing and production consistently emerged as the dominant NL hotspots, and nutrients in side streams often exceed those in food waste. These finding underscores the importance of tracking multiple, food-group-relevant nutrients and of

explicitly accounting for sidestreams, as both deepen our understanding of the nutritional value leaving the food system and reveal criticalities and valorisation opportunities that would otherwise remain invisible. Overall, avoiding FLW and redirecting nutrient-dense sidestreams toward human food use represents a win-win opportunity for both nutrition and environmental sustainability.

Keywords: nutritional losses, food waste, sidestreams, life cycle assessment, nutrition security