

Assessment and bio-valorisation of by-products from food industry in Europe

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Introduction: The EU Bioeconomy Strategy (*EC, 2018*) encourages the use of secondary bio-based resources to produce value-added products. However, the lack of harmonised information and quantitative data on the availability of these resources in different regions hinders the exploration of regional valorisation opportunities. In addition, the UN Sustainable Development Agenda (UN, 2015) does not outline targeted actions to manage food processing by-products, a type of secondary bio-based product, nor is there a uniform reporting procedure for by-products like the one for food waste in the EU (*EC, 2019*). This can result in under-reported resource flows and suboptimal usage. A study by *De Laurentiis et al. (2023)* carried out food loss, food waste and by-product accounting across the whole food supply chain in the EU using a material flow analysis approach. While the study provides a comprehensive overview of all the EU countries, it lacks detailed estimates for specific by-products. *Haller et al. (2022)* support the assumption that resource quantification can identify underutilised resource flows. *Soloha et al. (2024)* established a standard method for estimating the volume of specific food industry by-products and made estimates for eight Northern European countries. The present study uses the method developed by *Soloha et al. (2024)* to expand the geographical scope to other European (particularly EU) countries. This approach facilitates an overall estimation of by-products across the whole EU and enables comparison and identification of differences among individual countries.

Material and methods: The current study draws on the previous study by *Soloha et al. (2024)* which assessed the by-products of the food processing and manufacturing industry in eight Northern European countries: Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway, and Sweden. The present study uses the FAOSTAT database “Food Balances: Supply Utilization Accounts” to extract food production data from all the EU countries. The statistical data were compiled for the years 2015 to 2021, thus including the latest data available on food production quantities. The study selected 40 unique crop and livestock (excluding meat) food products from the production data of processed products. By-product volumes were calculated based on the compiled data from the analysed scientific and grey literature for the respective processed food products. For the analysis of bio-valorisation methods, only original scientific research articles were analysed, excluding review articles. Bio-valorisation is defined as the use of living organisms (such as microorganisms and macroscopic fungi) or their enzymes for valorisation purposes. The analysis included valorisation methods that solely use by-products derived from the studied crop and livestock products.

Results: The research presents an updated estimation of by-product volumes in each of the analysed countries and in the EU-27 between 2015 and 2021. The estimated by-product volumes provide an understanding of their availability, as well as the differences between individual countries. By-products are categorised as dairy, fruits and vegetables, roots and tubers, oils and fats, cereals, brewery and winery, and *other* (eggs, coffee, groundnut and cocoa) by-products.

Discussion and further outlook: The study provides a comprehensive overview of estimates of total annual by-product volume generated, and value-added products using bio-valorisation. It offers valuable data-driven insights to support the development of the circular bioeconomy. However, further research is needed to refine by-product estimations and evaluate their suitability for producing value-added products. Moreover, it is crucial to align by-product availability with a region's potential for circular bioeconomy growth because circular bioeconomy and bio-valorisation present various challenges. It is important to explore the environmental, technical, economic, and social aspects to ensure an efficient and equitable transition to a circular bioeconomy and a meaningful transition toward achieving sustainable development goals. Data-driven insights into by-product availability are a necessary precondition.

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