Urban biowaste valorisation – What is the menu? The H2020 HOOP project's state-of-the-art

M.A. Suárez[1], E. Gambuzzi[1], E. Vogiatzidaki[2], E. Skourtanioti[2]

[1]Technological Centre for Energy and Environment (CETENMA), Sofía 6-13, 30353, Cartagena, Murcia, Spain
[2]Draxis Environmental Solutions, 317 Mesogeion Avenue & Lokridos, 15231, Halandri, Athens, Greece
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Presenting author email: miguelangel.suarez@cetenma.es

Introduction

The amount of urban biowaste streams is expected to increase in the near future, as the Waste Framework Directive (2008/76/CE) establishes that separate collection of urban biowaste should be implemented in the EU by the end of 2023. However, the recycling routes considered are still limited to composting and anaerobic digestion and bioproducts' value is low. Searching for alternatives is a real challenge for cities and regions (solution adopters), since the offer of innovative technologies coming from scientific proposals, research projects, start-ups and technology-providers (solution developers) is wide. The uptake of a solution for biowaste treatment strongly depends on the pull from the adopter sectors, that are often hesitant to explore innovative valorisation systems due to the difficulty in quantifying risks (mainly related to technology readiness and bioproduct market) and benefits of innovative options. This acts as a barrier and locks the deployment of urban circular bioeconomy (UCBE).

The Horizon 2020 project HOOP aims to tackle barriers and unlocking UCBE projects by providing project development assistance to 8 European cities and regions. In this framework, HOOP has elaborated a portfolio of alternative technologies for valorisation of urban biowaste and urban wastewater sludge (UWWS) in order to provide cities and regions an overview of the available innovative circular solutions. In this work, we present assessment guidelines for the compilation and selection of mature technologies for biowaste valorisation. Our aim is to help adopters to bet on diverse solutions and to inform technology developers on adopter's expectations, contributing to foster UCBE and to create high added-value through technologies using biowaste as feedstock.

Materials and methods

The materials used for the development of the portfolio is extensive information from EU projects from different calls, especially Horizon 2020 (VALUEWASTE, SCALIBUR, WaysTUP!), but also LIFE, BBI-JU, Interreg, patent databases, scientific journals and bibliography, websites and correspondence with technology-providers. The methodology to develop the portfolio followed a three-step approach.

The **first step** is the selection of technologies under the following considerations:

• Material valorisation, to get a recycling operation rather than a recovery operation.
• Target urban biowaste. It includes household, parks and garden, markets and HoReCa waste, as well as UWWS.
• TRL of at least 5. This means that the technology is validated in a relevant environment (at least one existing pilot) and that the upscale to full market readiness can be financed with relatively small R&D funds or financing tools for medium- and low-risk projects.
• It needs to be a technology itself, not a combination of already established processes.

The **second step** consisted of the detailed description of technological aspects, providing their scientific background and the type of waste they valorise. For each of the technologies, the most relevant bioproducts have been identified and described and a list of patents provided.

The **third step** is a multidisciplinary analysis for the evaluation of the technologies run independently by partners not involved in the other steps, considering the following aspects:

• Techno-environmental. Indications on conventional products replaced and main environmental impact of the process, as well as the assessment of technological readiness level (TRL) (European Commission, 2017).
• Economic. Data on investment cost (CAPEX), operational costs (OPEX) and bioproducts market price.
• Legal. The regulatory framework (barriers and enhancers) both of the technologies and the bioproducts.
• Social. Analysis focused on community acceptance and consumer acceptance.

The number of solutions for urban biowaste and the maturity required to undergo the multidisciplinary analysis limited the number of technologies in the portfolio to 17.

Results and discussion

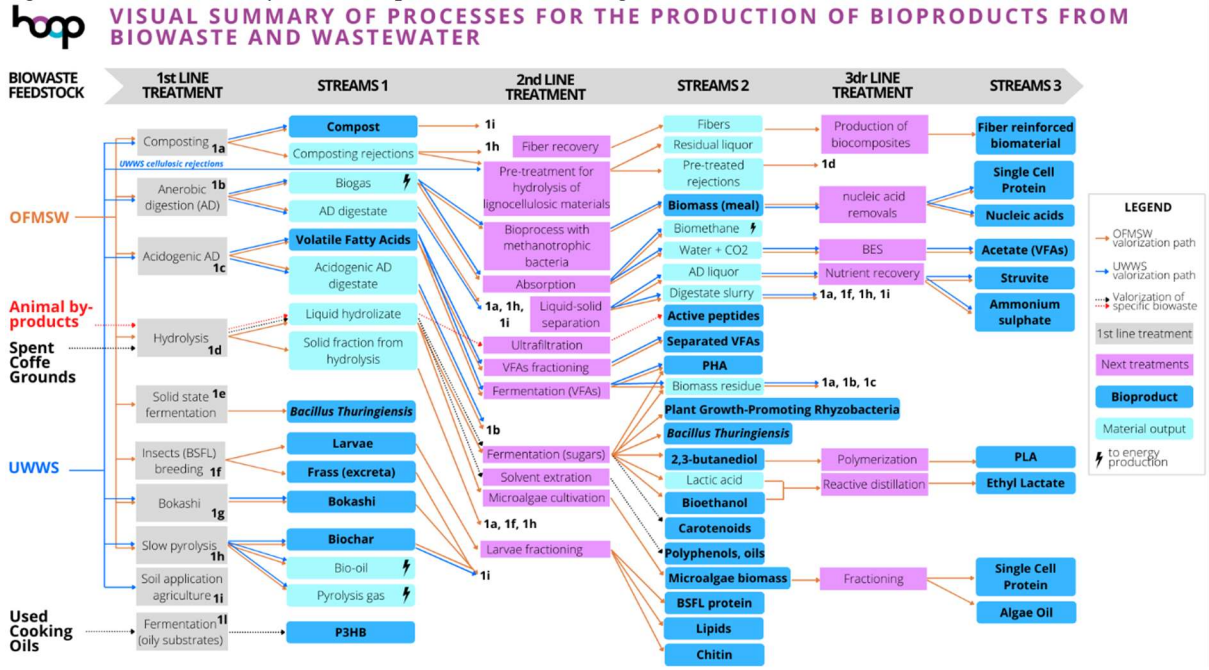
The application of the methodology resulted in a portfolio of 17 technologies for urban biowaste valorisation to be offered to HOOP cities and regions. Moreover, it was found that many technologies could be grouped under similar characteristics. Thus, the following classification system was proposed to ease the comprehension to solution adopters.

• Hydrolysis technologies. They have a previous step of hydrolysis to release nutrients used in later bioprocess.

• Partial anaerobic digestion technologies. They have similar approach as anaerobic digestion, but stopping in a step previous to biogas formation. A typical example is the production of volatile fatty acids.
• Specific biowaste: They require the separate collection of a very specific biowaste, like used cooking oils. This means a smaller amount to treat and, therefore, diverting from the bulk urban biowaste treated with another technology.
• Anaerobic digestion downstream. They treat and valorise fractions coming from anaerobic digestion, for example nutrients recovery from digestate or production of protein from biogas with methanotrophic bacteria.
• Insects. Biowaste is converted into meal by insects farming (yellow mealworm, black soldier fly larvae).
• Thermo-recycling. Thermal treatment is used for material valorisation (i.e. production of biochar by pyrolysis).
• Fibre valorisation. Application of lignocellulosic biowaste fibres for construction and packaging materials.
This classification can be practically applied through the diagram in Figure 1, in order to provide an orientation to the cities and regions on how to treat biowaste and get benefit from the UCBE concept:

From an economic point of view, the value of the bioproducts is a key factor for the feasibility which can be increased by downstreaming into higher added-value products. Social acceptance of the process is related to noise and odours. Meanwhile, the acceptance of bioproducts depends much on price and suitability.

Figure 1. Visual summary of HOOP portfolio of technologies for material valorisation of biowaste and UWWS



Conclusions

The work presented here gathers information on the **fundamentals** of available technologies at medium-high TRLs and the bioproducts obtained. It also provides **insights for the selection** depending on the adopters' needs. The main findings are: i) waste management solutions are multistep industrial processes, which might have different TRL, ii) different processes can provide the same function (i.e. thermal and enzymatic hydrolysis); iii) a technology might be applied to a variety of biowaste, tackling the fluctuation of feedstock availability. These findings imply a high flexibility and the possibility to tailor solutions based on the bioeconomy context in the city or region.

Hydrolysis technologies make biowaste suitable as feedstock of many processes, which makes them flexible, but the solid residue still needs further treatment. Insect farming is the most robust technology for low quality biowaste, but the bioproducts have very restricted market sector. Technologies requiring specific biowaste have limited impact on household biowaste valorisation but important implications for waste coming from markets or industrial by-products, where sorting is easier, purity is higher and usually less legal barriers on bioproducts.

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