The ELLIPSE Horizon Europe project: efficient and novel waste streams co-processing to obtain bio-based solutions for packaging and agricultural sectors

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Valorisation processes for heterogeneous organic waste are difficult to implement due to the presence of various impurities, therefore incineration and landfilling appear to be the most common ends of life (EoL) for these waste streams. This category includes paper sludge, mainly from the paper recycling process, and slaughterhouse waste, especially the contents of the digestive tract (also known as the bellygrass). Paper industries generate large amounts of solid waste and sludges with high variability in terms of quantity and composition during the various process steps. Paper industries is responsible for up to 17% of the total global waste (Karak *et al*, 2012) where most of the impurities are inorganic fillers (50-60% w/w) and ink particles (10-25% w/w) (Bajpai, 2013). Moreover, slaughterhouses represents another industrial activity responsible of several putrescible residues, such as digestive tract content (bellygrass) and partially digested feed, or other impurities such as plastics, metal pellets, stones, rope and boluses. The first category is the most prevalent: for instance, a cattle slaughterhouse produces about 60 kg of bellygrass corresponding to about 10% of the total weight of the animal (Jensen *et al*, 2016). Anaerobic digestion with biogas production represents an efficient and sustainable strategy for the valorisation of the organic waste, while the anaerobic digestate can be further processed to produce high value-added compounds such as bioplastics (e.g. polyhydroxyalkanoates, PHA) and biofertilizers.

ELLIPSE project aims to valorise slaughterhouse waste and paper and pulp sludge into cost-efficient PHAs for agricultural and packaging sectors, by the co-processing with other organic waste streams such as glycerol from the biodiesel industry and sludge from the dairy industry. Moreover, the project will maximize biowaste valorisation through the recovery of nutrients (N and P) from the organic waste to reduce the environmental impact of fertilizers production. The new strategies implemented will thus decrease the volumes of landfilled waste, opening new avenues for platform chemicals and bioplastics production while promoting water recycling and decreasing soil degradation, groundwater pollution and methane emissions.

ELLIPSE consortium consists of 13 partners from 8 different EU countries (Spain, Belgium, Portugal, Italy, Croatia, The Netherlands, Austria, Ireland) and integrates the knowledge and expertise of several disciplines to meet the high industrial requirements regarding purity and performance of bio-based products such as bioplastics and biofertilizers. The partners include 2 waste stream producer and manager, 4 technology developers, many industrial actors, of which 4 small and medium-sized enterprises and 2 bigger companies, plus the contribution of 2 companies with expertise in IPR and exploitation management and in ICT and decision-making tools development respectively, to accomplish the expected outcomes and increase the impacts of the results achieved. The project, which started in May 2023 and will last 48 months, has an overall cost of 7 million euros, of which 5.5 million euros has been funded by the European Union under the Circular Bio-based Joint Undertaking.

To efficiently valorise the heterogenous waste streams and reach the scalability of the new technologies proposed, ELLIPSE project will follow a 5-phase methodology:

- Phase 1: selection, analysis, and pretreatment of the waste streams to reduce impurities and increase the production of volatile fatty acids (VFAs) by acidogenic fermentation.
- Phase 2: utilization of VFAs to produce PHAs by biotechnological processes and recover of nutrients from acidogenic digestate through biological and physical-chemical innovative technologies to formulate biofertilizers with tunable kinetics of nutrient release.
- Phase 3: validation of PHA based bioplastics and bio-fertilizers for the application in personal-care and agricultural sectors.
- Phase 4: validation of different end of life alternatives (mechanical, chemical, enzymatic, and organic recycling) of obtained biobased prototypes and evaluation of the ELLIPSE value chain trough a full life cycle assessment.
- Phase 5: maximize the market uptake of the new biobased products by increasing consumer awareness and engaging key stakeholders.

Phase 1,2 and 3 will be implemented and demonstrated at pilot scale (up to TRL 7) as reported in fig.1.

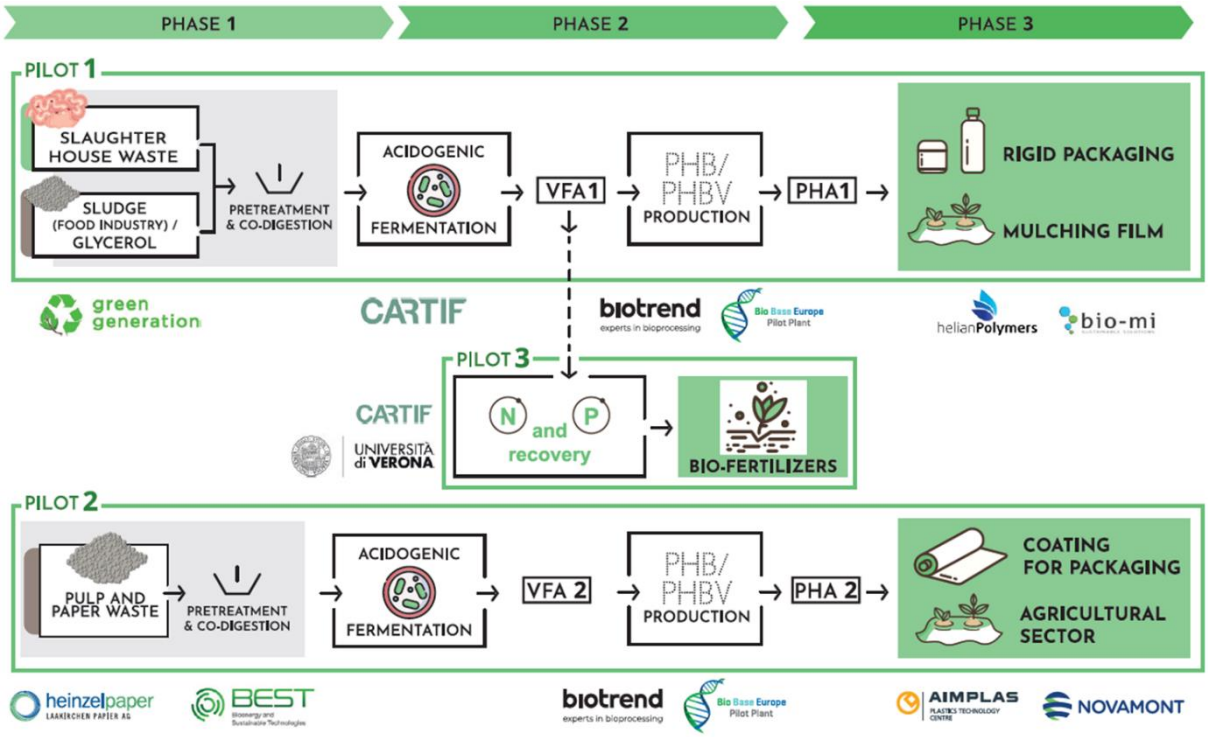

Figure 1-Scheme of the methodology implemented in the Pilot 1, 2 and 3 to convert heterogeneous waste streams into higher-value products.

In pilot 1 co-digestion of slaughterhouse waste with other organic waste (dairy sludge or glycerol) will be carried out with the aim of maximise odd-VFAs (propionate and valerate) production, which promote the accumulation of PHBV (Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)) in bacterial strain producers of PHAs. Copolymers with high valerate content (15-25%) are in fact more suitable to produce rigid packaging and mulching films due to better flexibility and melt resistance than PHB.
In Pilot 2 pulp and paper sludge will be firstly pretreat and then fermented as in pilot 1. In this case, copolymers with lower valerate content (5-10%) will be required to produce paper-based flexible packaging and coatings for biofertilizers.
In pilot 3 will be demonstrated the technical feasibility of two different technologies to recover nutrients (mainly nitrogen and phosphorus) while treating the digestate from acidogenic fermentation from pilot 1: (i) hybrid (photoautotrophic and heterotrophic) microalgae cultivation process, (ii) sequential pressure-driven membrane system. The nutrients recovered in pellet form will be used for the formulation of two types of controlled release granular fertilisers.
ELLIPSE project aims to process during its lifetime at least 100 tonnes of slaughterhouse waste and 20 tons of wastewater sludge derived from pulp and paper industry. In 10 years, the new technologies implemented will impact in the European bioeconomy by valorising 20,000 tons of rumen content waste and 50,000 tons of paper sludge per year.

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