Integrating composting within the biorefinery concept: closing the loop

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Biorefineries are based on four principles, sustainability, cascading, use of non-food resources and neutral carbon footprint. The trend in this new bioindustrial model is the use of organic waste to obtain multiple materials and compounds with high added value, as well as energy and biofuels. Agricultural and agrifood processing wastes are excellent raw materials for this growing bioindustry (Galanakis 2018). The combined fuel and value products from food waste is highly feasible under integrated bio-refinery concepts. Although the traditional use of these wastes for compost production is regarded as a low-value process because of the low economic benefit derived from the compost, i.e., 0−9 €/t (Evans and Wilkie, 2010), if composting is coupled to the recovery of organic leftovers from cascading extraction and conversion processes for the production of added-value compounds it will constitute a feasible and a sustainable way to returning the nutrients to the agricultural sector. Thus, the composting of the organic fractions that are generated in the different processes of treatment and extraction can be considered a key element to take full advantage of all the biorefinery fluxes and to recycle the organic matter in new crop cycles (Figure 1).

This work describes models for integration of composting in biorefineries that process agricultural and agri-food waste, and that constitutes one of the best examples of circular economy and sustainable industry. In addition, a case study developed in the context of the EU H2020 Agrimax project is analyzed. In this project two multi-feedstock biorefineries are built, one in Italy and another in Spain. A composting module is implemented in the Italian biorefinery that processes residues from the cultivation and processing of tomatoes. In this biorefinery, high added value products such as biogas and biocompounds with applications in packaging, pharmaceutical, cosmetics, agriculture, and food are produced. With the implementation of composting of organic fluxes, a product, compost, is obtained with application in agriculture that closes the cycle and widens the range of products obtained. In addition, organic fluxes from extraction and bioconversion processes are identified and its potential use as raw materials for composting is evaluated.

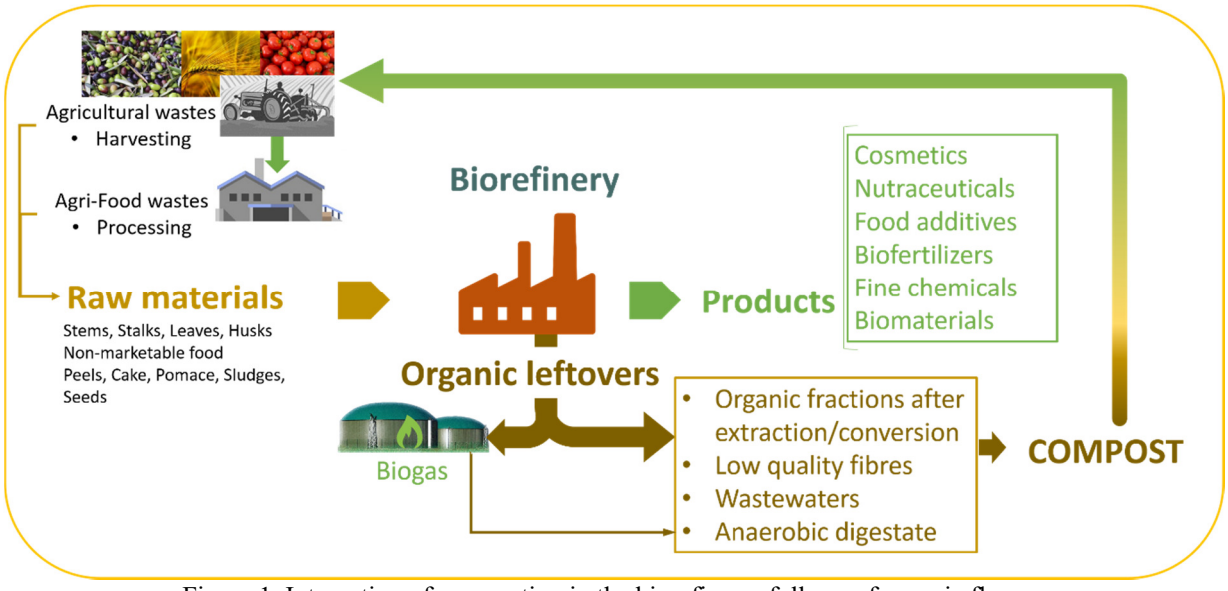

Figure 1. Integration of composting in the biorefinery: full use of organic fluxes

Food processing wastes include materials from spillage and degradation during industrial processing, as well as wastes produced when crops are sorted out if not suitable to process or during washing, peeling, slicing and boiling. These wastes can be solid or liquid and are rich in organic materials and biodegradable. Their volume and composition are variable and depends on the type of process, the plant or fruit, and the season (Galanakis, 2018). Approximately 700 million tonnes of agricultural waste are produced annually in the European Union (Pawelczyk, 2005). The loss of food in homes, food industry, restaurants and in the distribution chain, without

considering the production of the field during harvesting or cultivation, amounted to 89 billion tons in 2006 in the EU-27 (European Commission, 2010). This causes significant economic losses and many environmental problems. These wastes are currently only partially valorized for biofuel production, to spread on land, animal feed or composting, and they pose a threat to the global economy and environment. Many high-value biocompounds that can be produced from these wastes have been identified so far (Fritsch *et al.*, 2017; González-García *et al.*, 2019). The range of processing conditions, raw materials, and integration of cascade extractions and conversions can be so wide that the organic fluxes derived from them and its potential use as materials for composting should be analyzed case by case. Several biorefinery models for the full recovering of agricultural and agri-food wastes have been proposed and the potential organic fraction fluxes that can be suitable for composting are analyzed separately.

An inventory of the raw materials, products and residual organic fluxes of extractive processes identified in the two Agrimax biorefineries was made (Table 1). In its initial design, the Italian plant has a composting module. In this case, the composting module is contemplated from the beginning of the plant design, for the other residual materials its characteristics, suitable mixtures for composting, and potential integration in the biorefineries are analyzed.

Table 1. Inventory of potential organic fluxes for composting in the biorefineries of Agrimax.

Biorefinery	Raw materials	Products	Organic leftovers
Spain (Indulleida S.A., Lleida)	- Olive oil wastes (leaves and pomace) - Potato wastes (peel, pulp and juice) - Oat husks	- Aroma - Polyphenols - Protein - Fibres - Culture media for microorganisms	- Organic and liquid fractions from extraction processes - Low quality fibres
Italy (Azienda Agricola Chiesa Virginio, Mantua)	- Wheat bran - Tomato wastes (peels, non-marketable fruits, plant residues)	- Ferulic acid - Lycopen - Cutin - Hydrocompost - Compost - Biogas	- Water from tomato peel washing and flotation - Solid residue from hydrolysis - Sludge from anaerobic digestor

The integration of composting in biorefineries that process agricultural and agri-food waste allows obtaining a product with application in agriculture that closes the loop and widens the range of products obtained. This model is one of the best examples of circular economy and sustainable industry.

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