Design and scaling of a circular economy sequential bioprocess for the conversion of orange peels waste into agronomic bio-stimulants / biofertilizers

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ABSTRACT
This paper presents a new circular economy process for the valorization of orange peels waste, which is converted into bio-stimulants/biofertilizers and bacterial biomass with Plant Growth Promoting (PGP) activity. Fruit and vegetable crops raise serious environmental concerns, as they currently generate a large amount of plant residues that are not used to generate high value-added by-products. In Europe alone, around 37% of the vegetables produced are wasted (Capone, R., 2016). Poor management of this waste can have negative consequences, such as being a source of crop diseases and pests, and a source of greenhouse gases (methane) (Parra, S. et al., 2008). The FAO (Baudoin, W et al., 2017) estimates that in the world production of fruits, vegetables, roots, tubers and bulbs, food waste is 40-50%, depending on the product and the season. In Europe, food waste in fruit and vegetable production is around 46% and occurs throughout the food supply chain.

In recent years, there has been a growing interest in the reuse of these food wastes, not only to reduce their environmental impact through the circular production of by-products, but also to provide an economic benefit from the reuse of value-added products (Dwyer, K., Hosseinian, F. & Rod, M., 2014). With a circular economy approach, some of these wastes can be successfully "recycled", reused or valorised, improving both the economic and environmental aspects. Most of the waste that exists from orange harvesting comes from orange juice production. The management of orange waste presents certain challenges because, although it is biodegradable, it comes in a large quantity that is not easily handled. In the production of orange juice, two types of waste are generated, one solid and one liquid. The solid is the pressed orange peels from which the juice has been extracted; and the liquid comes from the pressing of the orange peels, which is considered the essential orange oil (Fig. 1) (Rueda,Y., Mancilla, L., & Parada, P., 2007).

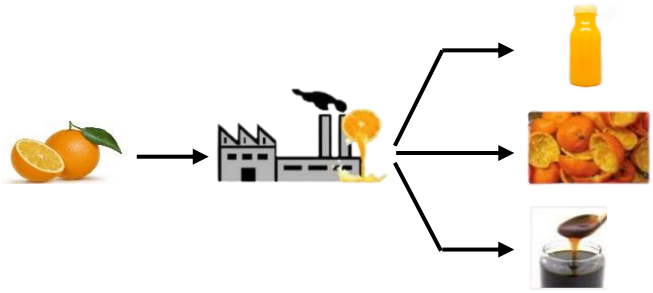

Fig. 1. *Scheme of the orange juice production*

The application of circular economy strategies to reuse and recycle nutrients from organic by-products and ultimately valorize them to obtain biostimulants ultimately represents an environmentally friendly solution to reduce waste levels. The choice of a suitable feedstock for this purpose is critical, considering some factors such as the absence of pesticides, economically viable collection and storage, production in large quantities and on a non-seasonal basis, and the absence of competition with other higher value uses (Xu, L. & Geelen, D., 2018).

The overall project objective pursues the investigation of new knowledge both in the obtaining/production and functional evaluation of biostimulants through the integration of circular economy strategies of agro-industrial organic wastes, specifically of Waste Fruits of horticultural and fruit production (WF-HFP). The project proposes the development of biphasic sequential bioprocesses: Enzymatic plus Lactic bacteria fermentation, for the conversion of WF-HFP into new bio-stimulants and the functional characterization of the experimental products designed, through the application of evaluation models of bio-stimulant potency.

Both residues will be subjected to the sequential bioprocess of enzymatic hydrolysis followed by bacterial fermentation with lactic acid bacteria. The bacterium used is endogenous to the orange, *Bacillus Sonorensis*. This bacterium presents important PGPbs properties for agronomic scaling.

The process starts with a first chemical phase that leads to the partial enzymatic degradation of orange peels in water, going from a solid state residue to a semi-solid residue with an increase of soluble compounds such as sugars or proteins. The second phase is a biological phase, where these molecules are metabolized and converted into new biostimulant products for agriculture, such as proteins by PGPbs bacteria (Fig. 2). The degradation phase is carried out in an aqueous solution, achieving the solubilization of the different compounds that form the orange peel, which have been characterized by HPLC-LC-MS. This solution is susceptible to metabolism by lactic acid bacteria, in this case, *Bacillus Sonorensis*.

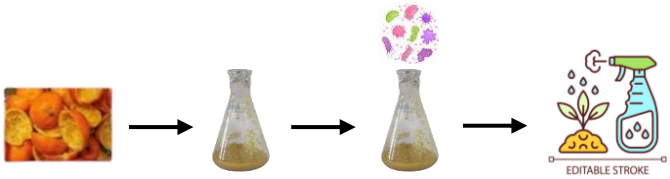

Fig 2. *Scheme of the two-phase process for the recovery of orange peels*

These peel-metabolizing bacteria belong to the metabolically versatile family Bacillus, specifically *Bacillus Sonorensis* (Fig. 3), known for their potential as Plant Growth Promoting bacteria (PGPb). *Bacillus Sonorensis* have been characterized as PGPB, exhibiting various activities such as nitrogen fixation and enzymatic activities like DNAse, amilase, protease, etc (Palaniyandi et al., 2018).

Fig. 3*. Bacteria Bacillus Sonorensis*

Conclusion

Through our biphasic process, we convert horticultural waste into a solution that can be metabolized and bio-transformed into biologically originated molecules using cultivation techniques with bacteria that possess PGPb capabilities.

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