Adding sustainability to the fruit and vegetable processing industry through solar-powered algal wastewater treatment

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Europe is the world's second largest producer of fruit and vegetables (FV). In the EU-28, the FV sector accounts for 17% of the total agricultural output value, of which 10% corresponds to vegetables and the remaining 7% to fruits. The importance of the sector is higher in most of the southern Member States, representing between one third and one quarter of their total agricultural output.

The FV sector is of strategic importance for European agriculture and the 500 million European consumers. It currently involves approximately 1 million farms specialising in fruit, vegetable and citrus fruit cultivation.

Derived from the above-mentioned fact, fruit and vegetables processing (FVP) industry is also one of the largest industrial sectors in Europe in terms of production, growth, consumption, and export. It includes the preparation, preservation, canning, freezing and drying of fresh FV and the manufacture of FV juices.

There were an estimated 10,000 enterprises across the EU-28 whose main activity was the FVP, employing 280.6 thousand persons. These enterprises generated EUR 39 billion of value added in 2013.

Key resources used by the FVP industry include water, raw materials and energy. Traditionally, the FVP industry has been a large water user. Water is used as an ingredient, an initial and intermediate cleaning source, an efficient transportation conveyor of raw materials, and the principal agent used in sanitising plant machinery and areas. It is estimated that around 200 Mm^3 wastewater was generated in 2014 by the EU FVP industry.

So although water use will always be a part of the FVP industry, it has become the principal target for pollution prevention. When FV are cleaned and processed, their residue is transferred into the water in both solid and dissolved form. These effluents contain high organic and nutrients loads, cleansing and blanching agents, disinfectants, salt, and suspended solids such as fibres, soil particles and plant pathogens. They may also contain pesticide and fungicide residues washed from the raw materials.

The composition of FVP wastewater differs by season, from facility to facility and also within the facility, the composition of the effluents changes according the product processed. Therefore, this composition cannot be generalised and a unique treatment option cannot be suggested.

Although FVP wastewater composition varies from one facility to the other, what they have in common is pollutant constituents and their potential negative effects on human and on aquatic and terrestrial ecosystems.

Direct discharge of FVP effluents into watercourses, although existing, is a forbidden practice today. Small FVP facilities have not usually in-situ treatment and they transport their effluents to sewer systems or municipal wastewater treatment plants, mixing them with the municipal sewage. However, due to its high organic and ammonium concentrations, these streams cause extra loading in the biological sewage treatment plant. As consequence, the treatment plant needs extra chemical addition, energy consumption and advanced operational skills to comply the effluent limits. Sometimes this wastewater transfer causes the treatment plant overloading in certain periods of the year, thus, avoiding its correct operation. Bigger facilities usually pre-treat their effluents by aerobic digestion, reducing the nutrient and organic loading before sending them to a municipal treatment plant for polishing. By treating the wastewater onsite, for potential reuse, it would permit the diversion of the wastewater from the local wastewater treatment plant, although, unfortunately, this is not a common practice in FVP companies. Furthermore, this in-situ treatment generates large amounts of sludge that has to be managed as a waste. The most common sludge disposal option in these cases is landfilling. Literature reveals that aerobic treatment of FVP effluents in Europe generated in 2014 around 90 Mm3 of sludge (waste content 98%).

This sludge landfilling has clear negative environmental aspects: it is an inefficient way to use organic feedstocks–wasting resources, reducing nutrients valorisation possibilities, and potentially increasing greenhouse gas emissions (103.5 Mt CO_2 equivalent). As the EU focuses on mitigating and preventing the consequences of global climate change there is a heightened awareness of the significant impact of landfill-generated methane emissions. This recognition is increasing the importance of recovering organics through composting, anaerobic digestion or other emerging methods, since it is the organics that are buried in landfills that are the source of this methane.

Proposed technological concept

LIFE ALGAECAN project will demonstrate the feasibility of an innovative in-situ treatment process for FVP effluents addressing the environmental problems associated with its current management and providing the relevant environmental and socio-economic values. The project LIFE ALGAECAN proposes a sustainable treatment model of high loaded and salty effluents that combines cost-effective heterotrophic algae cultivation with spray drying of the collected microalgae to obtain a product of commercial interest as raw material for the production of biofertilisers, animal feed, bioplastics or biodiesel. The prototype (Figure 1) will be powered by renewable energies (solar energy supported, when necessary, by biomass), which will minimise the carbon footprint and operating costs of the process.

The final effluent quality will be very high, allowing reuse for equipment cleaning and irrigation purposes. The project will also show an economic system that is easy to replicate on any site. The proposed system is a universal solution independent on the FVP effluent composition and is capable of eliminating the chemical and biological constituents, making it very practical for its use in any facility and easy to operate and maintain.

Nowadays, the common procedure for microalgae cultivation is autotrophic growth. The limiting factor of the cultivation in this case is the introduction of enough light. A feasible alternative is heterotrophic growth. In this case, the photosynthetic process gets suppressed and microalgae gain energy from alternative organic processes converting sugar into lipids. Irradiation is not now a limiting factor. Microalgae through heterotrophic nutritional mode facilitate high biomass productivities which provide an economic feasibility for large scale production. As consequence, large amounts of carbon and nutrients from external sources (i.e. wastewater streams) are consumed, what is one of its main advantages having in mind effluents treatment. Other main attractions of the heterotrophic growth approach are cost effectiveness, relative simplicity in operations and easy maintenance. This modality allows the use of practically any fermentor as a bioreactor.

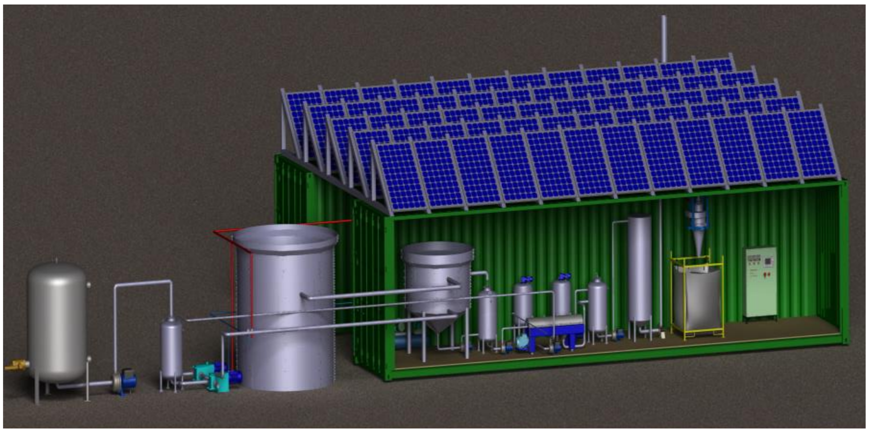

Figure 1. Process prototype.

Results

- Treatment of a minimum of 2 m^3/day of FVPI wastewater in a solar-powered prototype constructed in a specific way (demountable tanks and equipment containerisation) that makes it easy to transport and install/ uninstall, thus allowing flexibility in operating conditions.
- To obtain a high quality final effluent, 100% free of pathogens and xenobiotic compounds that can be reused (e.g. in irrigation and cleaning) or discharged into watercourses.
- To reduce the cost of FVPI treatment over 80% when comparing with a traditional aerobic treatment plant, by using solar radiation and biomass as energy sources and avoiding traditional costs associated with aerobic sludge management.
- To reduce by 100% the environmental impact associated with waste sludge generation in traditional aerobic treatment systems and its (usual) landfilling. This is translated in a saving of 1.15 kg CO_2 equivalent / kg of sludge avoided.
- To reduce by 100% nutrient losses associated with waste sludge generation in traditional aerobic treatment systems.
- To have a technology of general application to the fruit and vegetables processing sector, totally replicable, no matter the location of the facility or the product processed.

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