**From waste to energy: biogas production using olive pomace through anaerobic digestion**

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The main solid byproduct of virgin olive oil production, olive pomace (OP), contains a large amount of valuable compounds, such as polyphenols, that are highly applied in agriculture, cosmetics, and food sectors. Although it comes from an eco-friendly system, OP is considered highly phytotoxic, specifically due to its high polyphenol content; but extracting these compounds, not only reduces their environmental impact but also valorizes their potential. Moreover, the leftover olive pomace extraction residue (OPER) can be further utilized for sustainable biogas production through anaerobic digestion.

OP (Taggiasca cultivar), recovered from a local producer in Liguria region (Italy), was valorized through a high pressure and temperature extraction (HPTE) process to obtain a polyphenols-rich extract. Specifically, the extraction process involved the use of a hydroalcoholic mixture 1:1 (v/v) ethanol/water with a solid/liquid ratio of 1:10, operating at 180 °C for 90 minutes, performed under a nitrogen atmosphere. The extract was analyzed in terms of total polyphenol content (TPC) and antiradical power (ARP). OP and OPER were dried and then underwent physicochemical characterization, which included Fourier-transform infrared spectroscopy and thermogravimetric analysis. To evaluate the effectiveness of HPTE treatment on lignin fraction, the same extraction was performed on olive pomace stones (OPS). Finally, a mixture of anaerobic sludge with OP and OPER, OPS and OPS after HPTE treatment (OPSR) was subjected to anaerobic digestion for 42 days using an AMPTS II system.

HPTE extraction allowed the production of a polyphenol-rich extract with high ARP, resulting in a TPC of 6.3 mgCAE/mL and an ARP of 15.1 mgTE/mL. In terms of biogas production, OPR showed good methane production equal to 28.64 mLCH4/gVSadded, comparable to the biogas produced using only OPSR as initial feedstock, leading to biomass biodegradability rates of 37.6% for OPER and 23.6% for OPRS and a COD value reduction rate of 86%.

In conclusion, HPTE method proved effective in obtaining a polyphenol-rich extract with superior yields compared to unconventional techniques. Taken together, these results indicate that even after polyphenol recovery, OP remains a feasible feedstock for anaerobic digestion, thanks to the degradation of the lignin fraction, yielding substantial methane, which is essential for the future reduction of greenhouse gas emissions and effective waste management of agricultural residues.

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