

Techno-Economic Analysis (TEA) of Circular Economy Approach in the Valorisation of Pig Meat Processing Wastes

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Abstract : The pig meat industry generates large volumes of by- and co-products like blood, bones, skin, trimmings, organs, viscera, and skulls, among others, during slaughtering and meat processing and must be treated and disposed of ecologically. The yield of these by-products has been reported to account for about 10% to 15% of the value of the live animal in developed countries, although animal by-products account for about two-thirds of the animal after slaughter. It was selected for further valorization of the principal wastes produced throughout the value chain of pig meat production: Pig Manure, Pig Bones, Fats, Skins, Pig Hair, Wastewater, Wastewater sludges, and other animal subproducts type III. According to the potential valorization options, these wastes will be converted into Biomethane, Fertilizers (phosphorus and digestate), Hydroxyapatite, and protein hydrolysates (Keratin and Collagen). This work includes comprehensive technical and economic analyses (TEA) for each valorization route or applied technology. Metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and payback periods were used to evaluate economic feasibility. From this analysis, it can be concluded that, for Biogas Production, the scenarios using pig manure, wastewater sludges and mixed grass and leguminous wastes presented a remarkably high economic feasibility. Scenarios showed high economic feasibility with a positive payback period, NPV, and IRR. The optimal scenario combining pig manure with mixed grass and leguminous wastes had a payback period of 1.2 years and produced 427,6269 m³ of biomethane annually. Regarding the Chemical Extraction of Phosphorous and Nitrogen, results proved that the process is economically unviable due to negative cash flows despite high recovery rates. The TEA of Hydrolysis and Extraction of Keratin Hydrolysates indicate that a unit processing and valorizing 10 tons of pig hair per year for the production of keratin hydrolysate has an NPV of 907,940 €, an IRR of 13.07%, and a Payback period of 5.41 years. All of these indicators suggest a highly potential project to explore in the future. On the opposite, the results of Hydrolysis and Extraction of Collagen Hydrolysates showed a process economically unviable with negative cash flows in all scenarios due to the high-fat content in raw materials. In fact, the results from the valorization of 10 tons of pig skin had a negative cash flow of 453 743,88 €. TEA results of Extraction and purification of Hydroxyapatite from Pig Bones with Pyrolysis indicate that unit processing and valorizing 10 tons of pig bones per year for the production of hydroxyapatite has an NPV of 1 274 819,00 €, an IRR of 65.43%, and a Payback period of 1,5 years over a timeline of 10 years with a discount rate of 10%. These valorization routes, circular economy and bio-refinery approach offer significant contributions to sustainable bio-based operations within the agri-food industry. This approach transforms waste into valuable resources, enhancing both environmental and economic outcomes and contributing to a more sustainable and circular bioeconomy.

Keywords : techno-economic analysis (TEA), pig meat processing wastes, circular economy, bio-refinery

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