Process optimization, techno-economic and life cycle analyses for the extraction of valuable compounds from agri-food residues

Farid Soltanipour[1], F. Donsì[1], G. Ferrari[1,2]

[1] Department of Industrial Engineering, University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano (SA), Italy
[2] ProdAl scarl, Via Giovanni Paolo II, 132, 84084 Fisciano (SA), Italy
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Presenting author email: fsoltanipour@unisa.it

Introduction

Nowadays, agri-food residues are considered as a cheap source of a gamut of bio compounds, which include carbohydrates, proteins, fats, oils, antioxidants, etc. Thus, biomass valorization processes are extremely useful to obtain natural high value-added ingredients and, at the same time, contribute at reducing the environmental impact caused by the accumulation of bio-wastes(Zalazar-García et al. 2020). Moreover, they could potentially help increasing the return of agro-industrial SME's, in line with the UN2030 agenda's goal of improving sustainability and protecting natural resources.

Among the different valuable biomolecules present in agri-food residues, phenolics are considered as a class of compounds of high economic interest, and concentrated polyphenolic extracts have different applications as ingredients in the formulation of foods, food supplements, cosmetics and pharmaceutical products(Croxatto Vega et al. 2020).

To recover phenolic compounds from agrifood biomass, it is crucial to individuate appropriate separation processes enabling to preserve their functionality and quality while maximizing the extraction efficiency. Numerous unit operations are involved in the process, from the pretreatment of the biomass, to the extraction and downstream processing, and several operating variables play a role in determining the overall valorization process effectiveness. Therefore, carrying out a sensitivity analysis and optimizing the processing parameters requires extremely time-consuming and expensive procedures. Thus, simulation and modeling can be extremely useful for the optimal design of such a process and the selection of the most effective processing conditions(Okoro et al. 2022).

Methods

This paper presents the results obtained from the simulation of the polyphenols extraction process from cherry pomace utilizing SuperPro Designer software Fig.1. The conventional solid-liquid extraction technique was considered as the basic scenario for the process design. In the first step, the parameters involved in extraction such as temperature, time, and solid-to-liquid ratio were optimized, and once a suitable mathematical model describing the kinetic of phenolics release was individuated, it was used to design the extraction process. Material and energy balance calculations were done together with equipment size evaluation. Techno-economic and life cycle analyses were also conducted to evaluate the process sustainability(Adeyi et al. 2022).

As an alternative to the basic scenario, three novel and green technologies, Pulsed Electric Field (PEF), Ultrasound (US), and High-Pressure Homogenization (HPH) were introduced in the processing line, in the pretreatment stage of the biomass or to assist the extraction process, with the aim of increasing the extraction yield, and these new scenarios were analyzed. Techno-economic and life cycle analyses were performed also in this case and the most appropriate configuration of the polyphenol extraction processing line from an economic and environmental point of view was individuated.

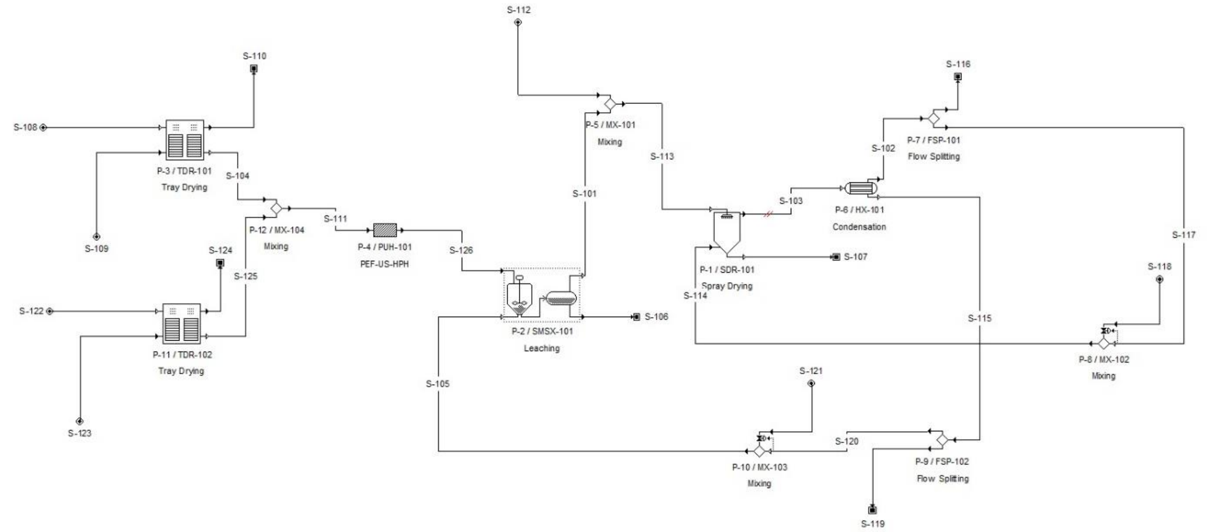

Fig.1 Basic scenario for polyphenols extraction process from cherry pomace utilizing SuperPro Designer software.

Conclusions

Although the data used in this research were obtained on a laboratory scale, thanks to SuperPro Designer software, they could be generalized to an industrial scale. In summary, it can be concluded that the use of novel and green technologies significantly increases the yield for the extraction of polyphenols from cherry pomace, but the costs and environmental impacts of the use of each of these technologies vary greatly and according to the results of the techno-economic and life cycle analyses, the most appropriate configuration of the polyphenol extraction processing line can be selected. The findings of this study can be considered as a starting point for designing a biorefinery process for agri-food residues valorization and moving toward the implementation of the circular bioeconomy concept.

References

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