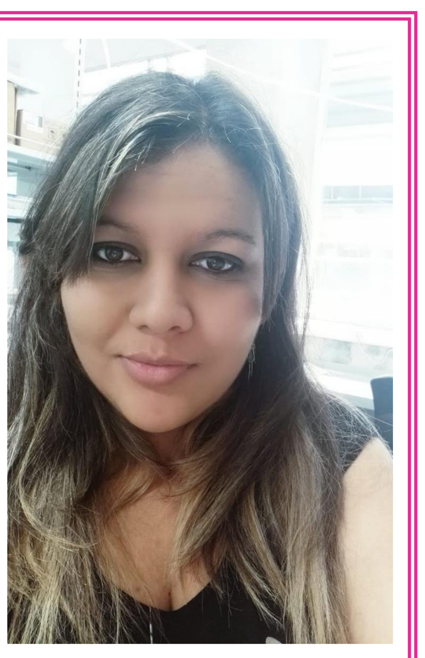
Economic feasibility of supercritical fluid extraction of antioxidants from fruit residues



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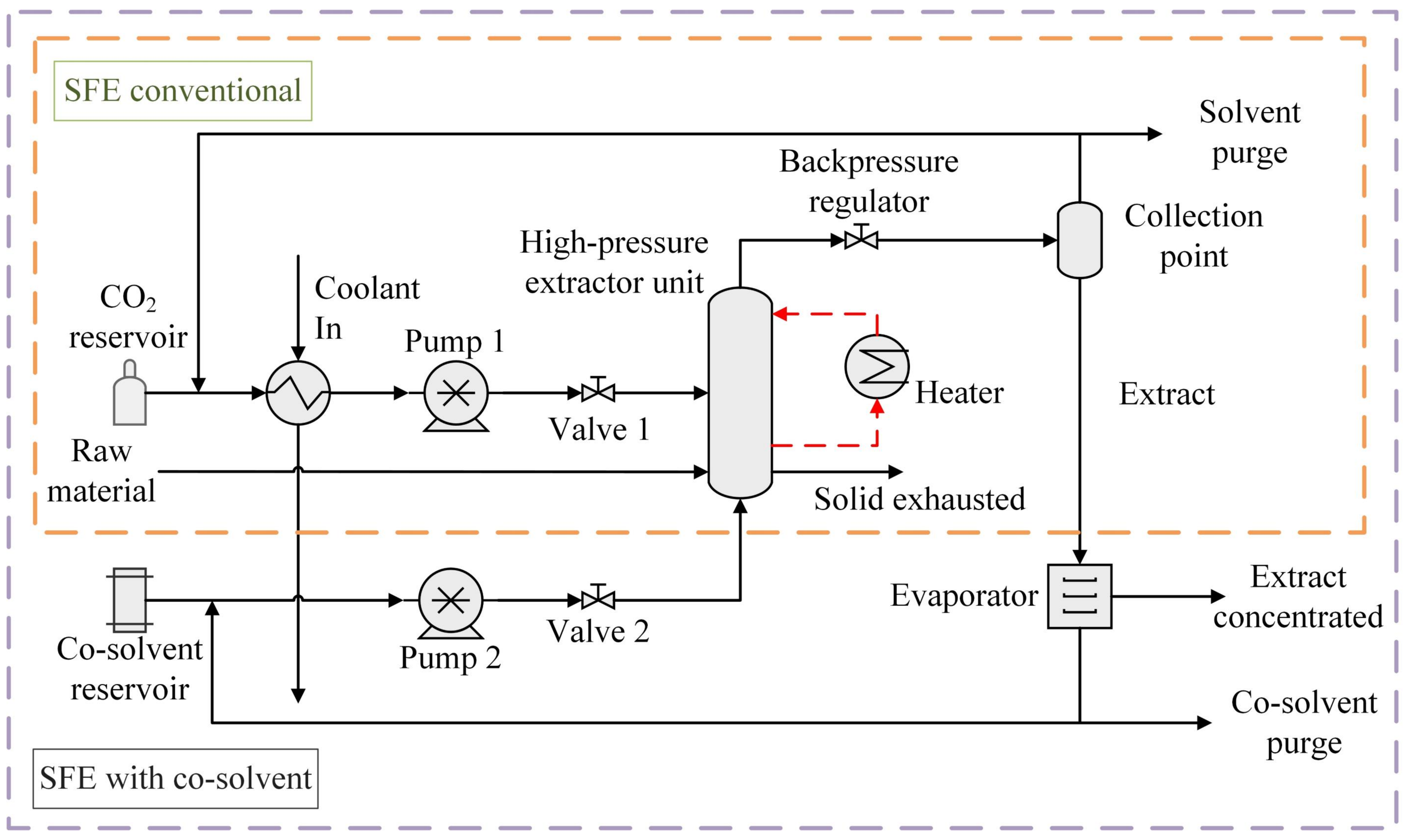
Introduction

Each year, large quantities of residues are generated by fruit processing industries, and in most cases, these are disposed of in landfills. In departments such as Norte de Santander, located in the northeast of Colombia, there is a great variety of crops. Fruits such as mango, strawberry, yellow passion, raspberry, avocado, orange, mandarin, lemon, peaches, açaí berry, among others, are some of the fruits cultivated in this department (MinAgricultura, 2019). The processing of these fruits generates waste such as mango and açaí berry peels, and yellow passion fruit and raspberry seeds. The composition of these residues presents a high potential for the extraction of natural compounds like the polyphenols, which have beneficial effects on health (Shilpi et al., 2013). Among the technologies available for the extraction of bioactive compounds, Supercritical Fluid Extraction (SFE) has emerged as a promising technology for these processes. For the implementation of SFE-based extraction processes it is necessary to know the economical aspects of the process. An economic analysis allows to identify the minimum processing scale, payback period, net present value (NPV) and profit margin.

Methodology

Different SFE schemes have been proposed to improve extraction yields. In this paper, two SFE schemes are considered, which are presented in Figure 1. The design of the processes is performed in the Aspen plus software considering a flow rate of 100 kg/h as a basis for simulation. The extraction conditions are taken from studies reported in the literature (see Table 1).



The economic analysis is based on the methodology and indicators presented by (Serna-Loaiza et al., 2018). The cost associated with raw materials, solvent (CO_2), co-solvent (ethanol) are 0.022 USD/kg, 0.45 USD/kg and 0.87 USD/kg, respectively. As economic indicators, the net present value (NPV), profit margin, payback period and minimum raw material flow are estimated. It is considered that mango peel, yellow passion fruit seed, raspberry seeds, mandarin peel and açaí berry extracts have sales prices of 12.55, 16, 9, 8 and 1.47 USD/kg, respectively (Alibaba.Com, 2021).

Table 1. Extraction conditions reported in the literature for the raw materials

Raw material	Pressure	Temperature	Co-solvent concentration	Yield %	Reference
Mango peel	20 MPa	50°C	Ethanol 20%	8.2	(Sánchez-Mesa et al., 2020)
Yellow passion fruit seed	25 MPa	50°C	-	18.5%	(Oliveira et al., 2013)
Raspberry seeds	300 bar	40°C	-	8.82%	(Marić et al., 2020)
Mandarin peel	220 bar	80°C	Ethanol 5%	34.76%	(Franco-Arnedo et al., 2020)
Açaí berry	490 bar	70°C	-	45.4%	(De Cássia Rodrigues Batista et al., 2015)

Results & Discussion

Figure 2 and Table 2 present the results of the economic analysis for the raw materials analyzed in this work. Table 2 shows the influence that the use of a co-solvent has on raw material costs. The extractions of mango and mandarin used ethanol as a co-solvent. An increase in this item can be seen in comparison with the other raw materials. Additionally, it is evident that using a higher concentration of co-solvent also contributes to the increase in these costs.

In addition, the extraction yield and the costs of the extracts for each raw material had a great influence on the results of the economic analysis. However, for the scale analyzed, all the processes presented a positive profit margin. The most promising raw material among those analyzed is passion fruit seed. It has the highest profit margin, the lowest payback period and the lowest minimum raw material flow. Therefore, the potential of this residue as a raw material for SFE processes is evident.

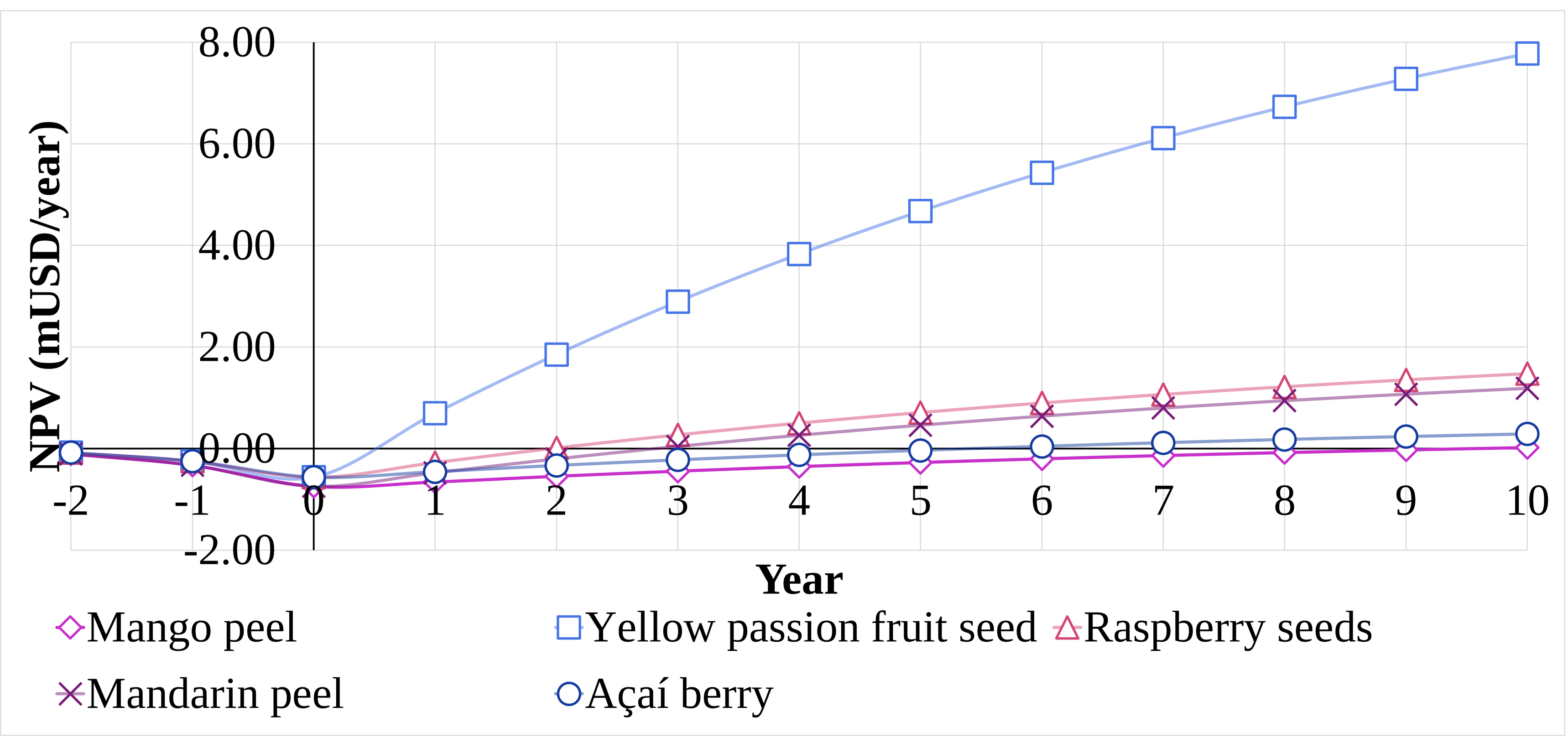


Figure 1. NPV for each raw material base on a calculation base of 100 kg/h

Table 2. Economic indicators calculations for a calculation base of 100 kg/h of raw material to obtain antioxidants

Item	Mango peel	Yellow passion fruit seed	Raspberry seeds	Mandarin peel	Açaí berry
Raw Materials	58.64%	10.34%	10.34%	30.08%	10.34%
Utilities	13.50%	33.46%	33.46%	22.83%	33.46%
Maintenance	5.36%	10.09%	10.09%	9.06%	10.09%
Labor	3.69%	9.14%	9.14%	6.23%	9.14%
Fixed & General	3.91%	7.76%	7.76%	6.62%	7.76%
Plant Overhead	4.75%	10.11%	10.11%	8.04%	10.11%
Capital Depreciation	10.14%	19.10%	19.10%	17.15%	19.09%
Total cost (mUSD)	0.84	0.34	0.34	0.50	0.34
Production Cost [USD/kg]	11.69	2.09	4.38	4.92	1.12
Profit margin	6.87%	86.94%	51.29%	38.44%	23.63%
Payback period (year)	9.67	0.45	1.97	2.84	5.50
Minimum flow (kg/h)	98.30	5.13	29.52	38.10	72.61

Conclusions

It was demonstrated that economic viability depends mainly on the characteristics of the antioxidant obtained in each case and that this finally defines the sales price. However, two predominant factors were decisive: the overall efficiency of utilizing the whole residue and the total yield of extracts obtained from each residue. The above factors contributed to the production of a low-cost extract from yellow passion fruit seeds. Additionally, the influence of the cost of the co-solvent in the feasibility analysis became evident.

Acknowledgments

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