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Catechin Extraction from a By-product of Habanero Pepper (Capsicum Chinense) Using Green Technologies

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Abstract

Catechin is a flavonoid widely distributed in plants. It plays a crucial role in cardiovascular protection thanks to its ability to inhibit platelet activation and enhance vasodilation. It modulates various cell signaling pathways involved in the progression of neurodegenerative and metabolic diseases, which has increased interest in it as a bioactive compound with high functional value (Mangels & Mohler, 2017; Ferrari & Naponelli, 2025). In this context, the habanero pepper (Capsicum chinense), an emblematic crop of the Yucatan Peninsula is widely recognized for its distinctive color, aroma, and flavor. It has a high polyphenol content in its leaves, including catechin, quercetin, rutin, gallic acid, cinnamic acid, and chlorogenic acid. However, it is estimated that about 20 % of production is industrialized, while the rest is discarded after harvesting the fruit, generating approximately 1.5 million by-products annually. Considering the importance of this crop to regional identity, it is essential to take advantage of these by-products to explore new sources of bioactive compounds (Statistical Yearbook of Agricultural Production, 2024). For this use to be viable and compatible with functional foods, it is essential to design safe and sustainable extraction strategies. Natural deep eutectic solvents (NADES) emerge as a superior alternative to conventional solvents: they offer more economical, ecologically sustainable, and highly selective extractions for bioactive compounds of interest. Additionally, their composition from natural compounds facilitates the incorporation of the extract into food matrices.The objective of this study was to obtain catechin from habanero chili pepper (Capsicum chinense) leaves using NADES in combination with ultrasound-assisted extraction (UAE). A preliminary design allowed for the evaluation of different hydrogen donors (glycerol, glucose, and fructose), identifying the choline chloride-fructose system as the most efficient for polyphenol recovery (CTP) and antioxidant capacity (Ax). Analysis of individual polyphenols by UPLC revealed the presence of various phenolic acids and flavonoids, with catechin standing out as the compound with the greatest potential for optimization. Targeted optimization of catechin showed that the NADES conditions (molar ratio and water percentage) significantly influenced its recovery, yielding a quadratic model with adequate predictive capacity ($R^2 \approx 0.76$). The optimal conditions were 1 : 3.4 mol/mol (choline chloride:fructose) with 84% water, predicting an optimal value of 146.53 mg/100 g Dry Leaf (DL). In summary, habanero chili leaves are emerging as a sustainable source of catechins through environmentally friendly extraction using NADES-UAE. Optimizing parameters such as molar ratio and water content using response surface methodology (RSM) maximizes the selectivity and concentration of these bioactive compounds. This strategy not only promotes the valorization of agro-industrial waste but also opens new avenues for

incorporating functional ingredients into food, in line with the Sustainable Development Goals (SDGs).

Keywords: Green extraction technologies, Catechins extraction, Natural Deep Eutectic Solvents (NADES), Response Surface Methodology (RSM)

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