Bioactive Phenolics from Aromatic Plants: Chemical Signatures and Anti-Inflammatory Effects on Intestinal Cells

Manuela Machado[1], Sara Silva[1], Eduardo M. Costa[1]*

Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal
*emcosta@ucp.pt

CATÓLICA
CBQF · CENTRE FOR BIOTECHNOLOGY AND FINE CHEMISTRY ASSOCIATE LABORATORY CBQF

PORTO

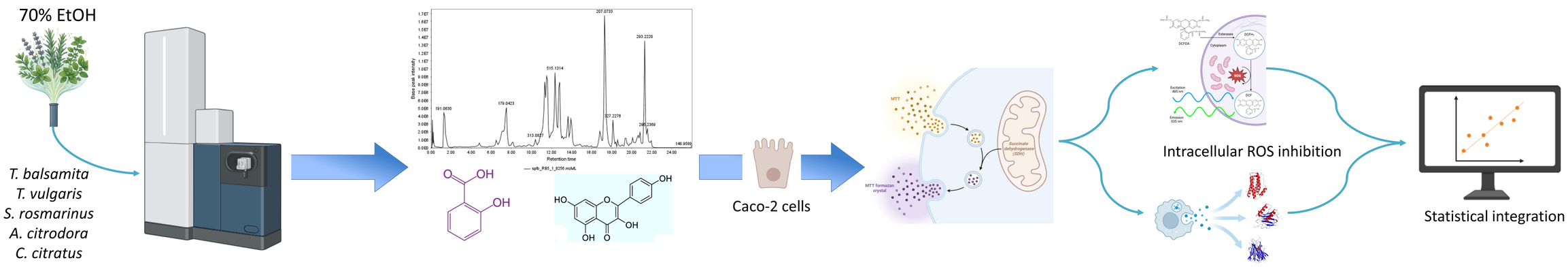
Introduction

Aromatic plants constitute a rich and largely underexplored reservoir of bioactive phenolic compounds — flavonoids, hydroxycinnamic acids, and polyphenolic derivatives — whose structural diversity underlies a broad spectrum of biological activities. Their distinct chemical signatures, shaped by hydroxylation patterns, glycosylation states, and conjugation with organic acids, are key determinants of their bioavailability and therapeutic potency. These secondary metabolites have been shown to modulate critical inflammatory pathways in intestinal epithelial and immune cells, notably through inhibition of NF-κB signaling, downregulation of pro-inflammatory cytokines (IL-6, IL-1β, TNF-α), and suppression of COX-2 and iNOS activity. Beyond direct anti-inflammatory action, phenolic compounds can reinforce epithelial barrier integrity and positively modulate gut microbiota composition, adding further relevance to their role in intestinal health. Inflammatory bowel conditions, characterized by chronic mucosal inflammation and significant impact on quality of life, remain a major therapeutic challenge — making the search for effective and safe natural alternatives increasingly urgent.

Objectives

- Characterize the phenolic profile of selected aromatic plants
- Evaluate their anti-inflammatory potential in intestinal cell models
- Explore the relationship between chemical composition and biological activity

Methods



Results

Table 1. Primary LC–MS–identified constituents and chemical classes of the five plant extracts.

Sample	Primary Identified Constituents*	Dominant Chemical Class	Total Phenolic Content**
T. balsamita	Apigenin; Caffeic acid; Luteolin-7-O-glucoside; Rosmarinic acid; Neochlorogenic acid	Phenolic acids + flavonoids	30,97
T. vulgaris	Luteolin; Luteolin-7-O-glucoside; Luteolin-4'-O-glucoside; Rosmarinic acid; Caffeic acid	Flavonoids + phenolic acids	7,73
S. rosmarinus	Luteolin-7-O-glucoside; Luteolin-4'-O-glucoside; Apigenin-7-O-glucoside; Apigenin; Rosmarinic acid	O-glycosylated flavonoids	7,04
A. citrodora	Acteoside (verbascoside); Eriodictyol; Apigenin; Luteolin; Cirsimaritin	Phenylethanoids + flavonoids	2,56
C. citratus	Isoschaftoside; Caffeic acid; p-Coumaric acid; Eriodictyol; Scoparin	C-glycosylated flavonoids	5,48

*Compounds represent identified constituents from LC–MS annotation
** Values in g of Chlorogenic Acid Equivalents/100 g of extract

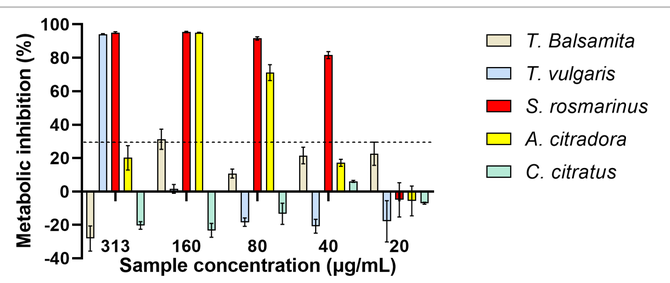


Figure 1 – Cytotoxicity results of the tested extracts. Dotted line represents the 30% cytotoxicity limit as defined by the ISO 10993-5:2009 standard. Bars represent mean ± SD

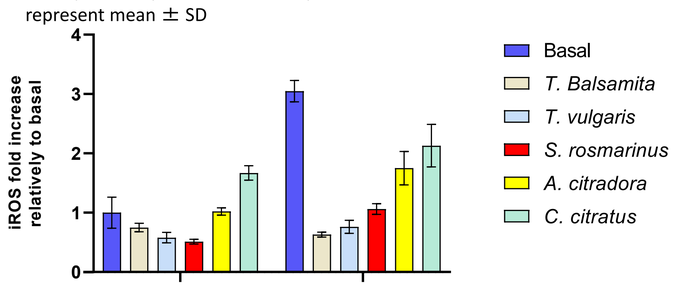


Figure 2 – Intracellular ROS levels in Caco-2 cells in the presence of the tested extract in the absence and presence of TBHP stimuli. Bars represent mean ± SD.

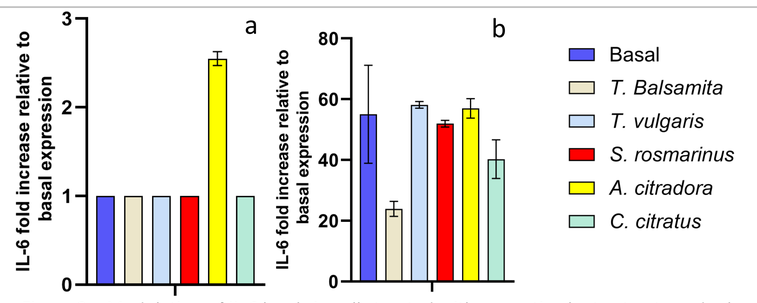


Figure 3 – Modulation of IL-6 levels in cells treated with aromatic plant extracts under basal and stimulated conditions. Bars represent mean ± SD.

Table 2. Integrated summary linking structural features with observed biological responses.

Sample	Standard Feature	IL-6 Modulation	iROS Modulation	Interpretation
T. balsamita	Flavonoids (including aglycones)	Strong	Strong	Results consistent with flavonoid-driven activity
T. vulgaris	Phenolic acids + flavonoids	Moderate	Moderate	Balanced activity reflecting mixed phenolic composition
S. rosmarinus	*O*-glycosylated flavonoids	Moderate	Moderate	Moderated response likely linked to glycosylated flavonoid forms
A. citrodora	Phenylethanoids + flavonoids	Strong	Strong	Targeted activity associated with acteoside
C. citratus	C-glycosylated flavonoids	Variable/Lower	Moderate	Structurally stable profile associated with less pronounced effects

Conclusions

Distinct chemical profiles across the extracts align with their biological responses, with stronger IL-6 and ROS modulation observed in less conjugated systems. *T. vulgaris* and *A. citrodora* showed the most pronounced effects, highlighting the role of structural features in bioactivity. Overall, extract functionality is driven by composition, supporting targeted selection for specific applications.

Acknowledgements

This work was supported by National Funds from FCT - Fundação para a Ciência e a Tecnologia through contracts 2023.15056.TENURE.057 and 2023.15056.TENURE.049 and via projects UIDB/50016/2025 and LA/P/0076/2020 (https://doi.org/10.54499/LA/P/0076/2020). Additional funding was secured via projects FERDINAND (COMPETE2030-FEDER-00822600) and WiSe (COMPETE2030-FEDER-00820800) funded by FEDER, PITD—Programa Inovação e Transição Digital.