Cost-Effective Valorization of Factory Tea Waste: Enhancing Circular Economy Practices

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Introduction


Tea seeds


Tea Factory waste


Domestic tea waste

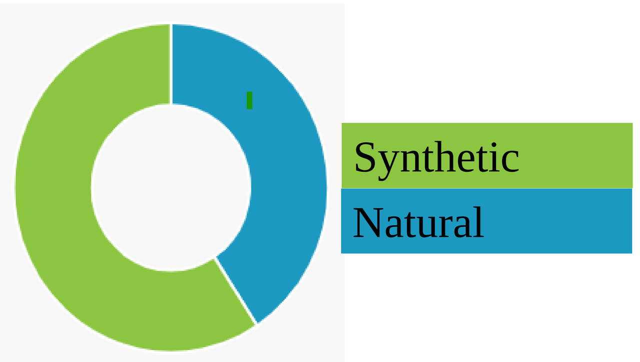
1.3 USD billion in 2020-e

1.8 USD billion in 2025-p

CAGR of 6%

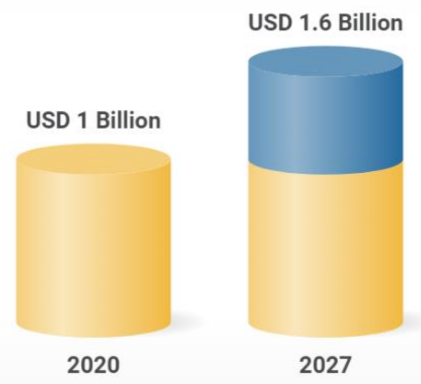
The global anti-oxidant market is projected to be worth 1.8 USD billion in 2025 with an CAGR of 6%.

(Source: https://www.marketsandmarkets.com/Market-Reports/food-antioxidants-market-91651246.html)



Global antioxidant market share by type, 2020

(Source: https://www.fortunebusinessinsights.com/industry-reports/food-antioxidants-market-100789)



Global polyphenols market: $1B in 2020 ➔ projected $1.6B by 2027, 7.1% CAGR.

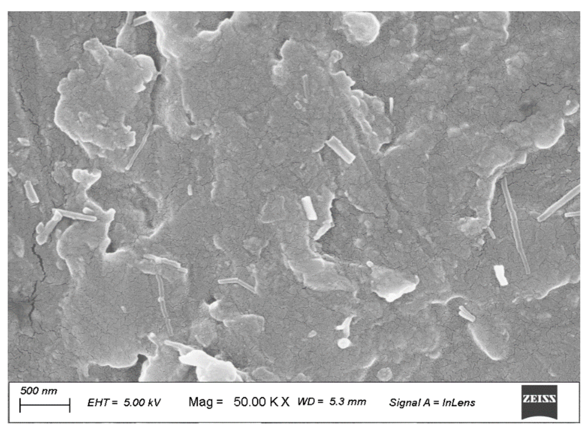
Methodology


Factory tea waste

Liquid extract

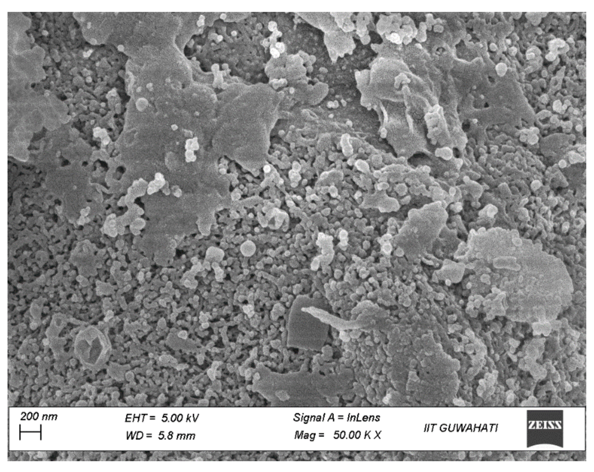
Freeze drying


Residue after extraction

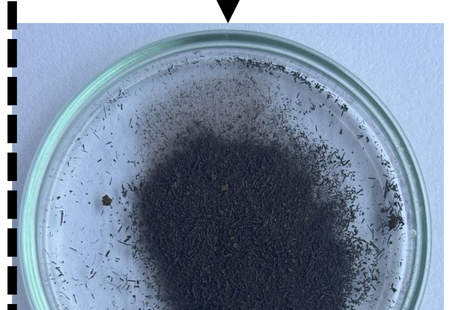


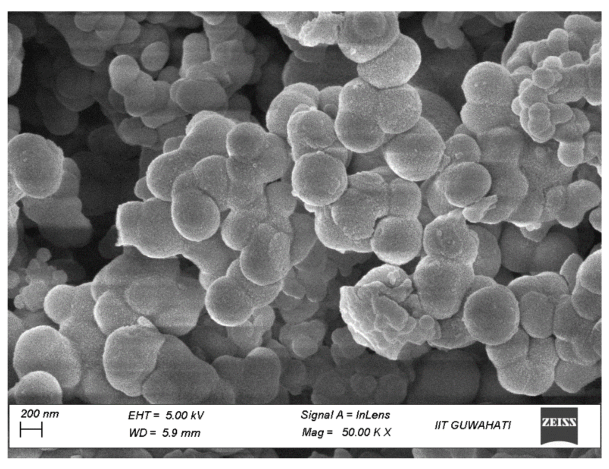
Hydrothermal carbonization


Hydrochar



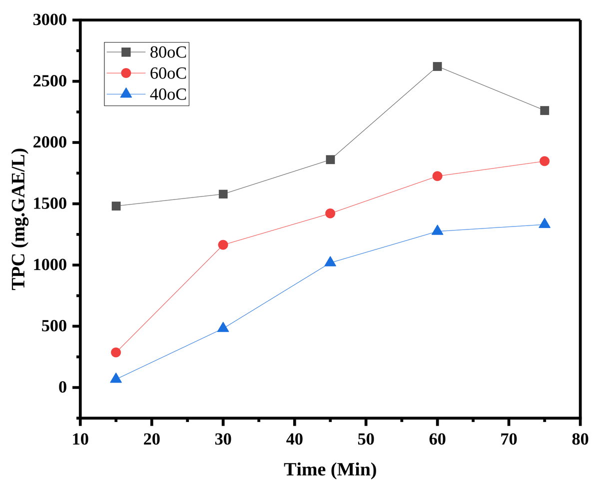
Fenton Activation

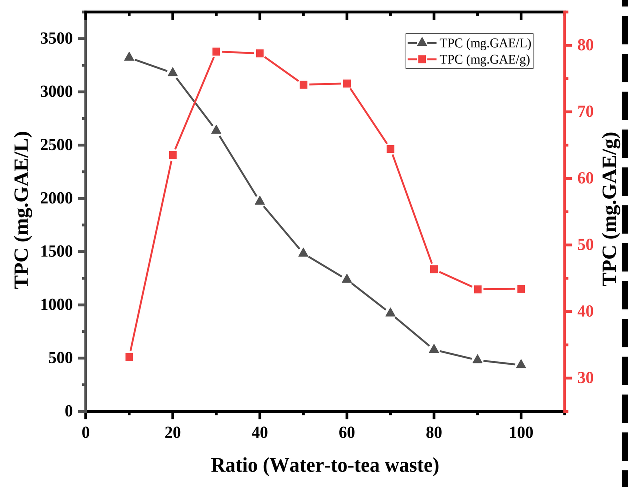

Activated Hydrochar

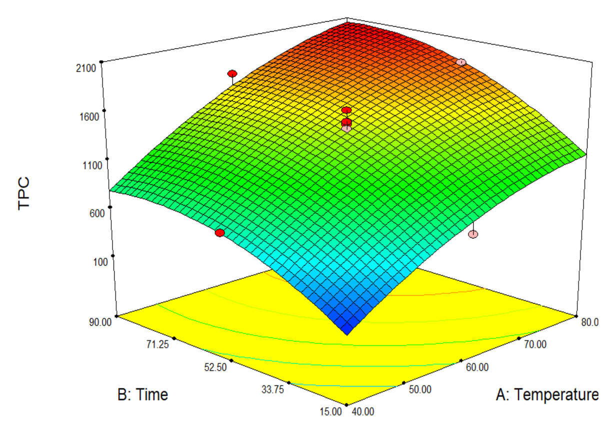


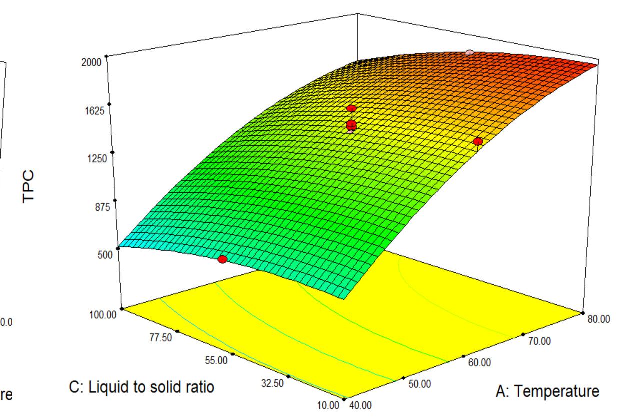
Results and discussions

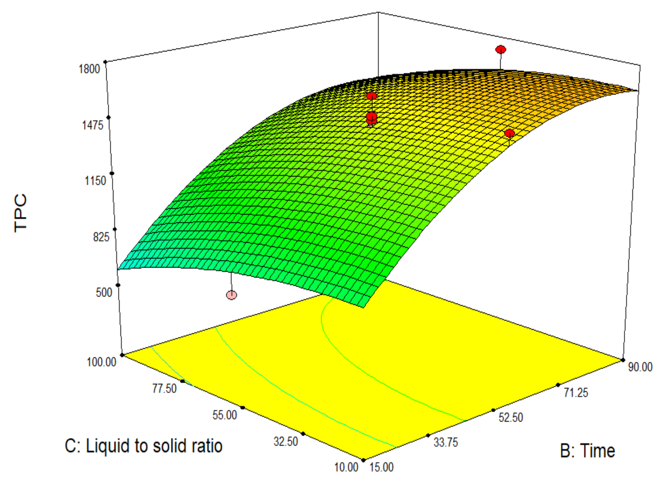
Optimization of extraction parameters







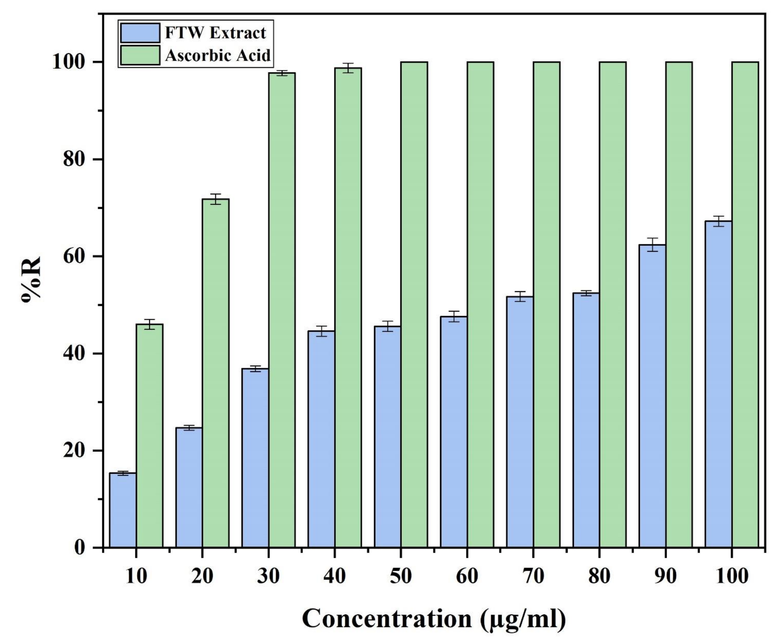


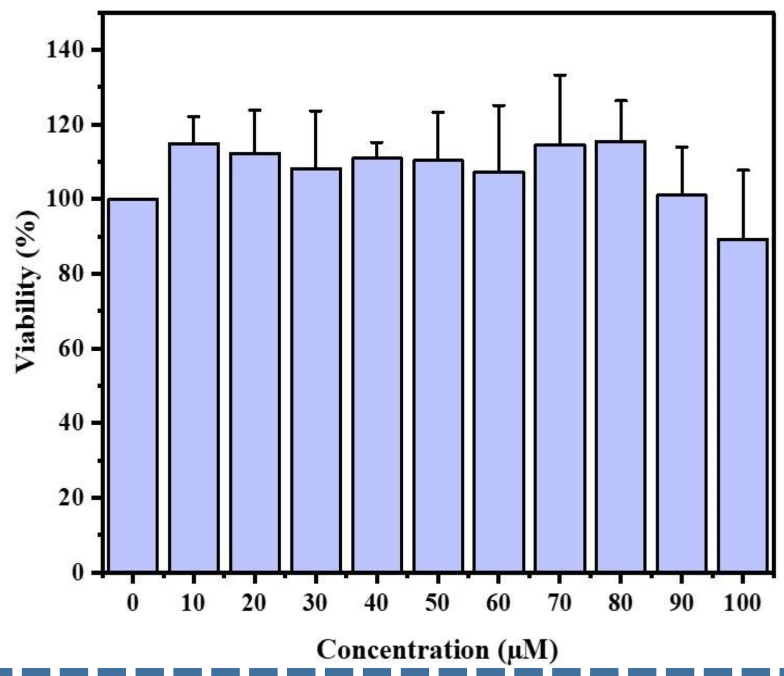


The optimal polyphenol extraction conditions were a water-to-factory tea waste ratio of 30:1 mL g^{-1}, temperature of 80°C, and extraction time of 60 min. At the optimized condition, the recorded polyphenol content was 2635.36 ± 52.07 mg GAE/L.

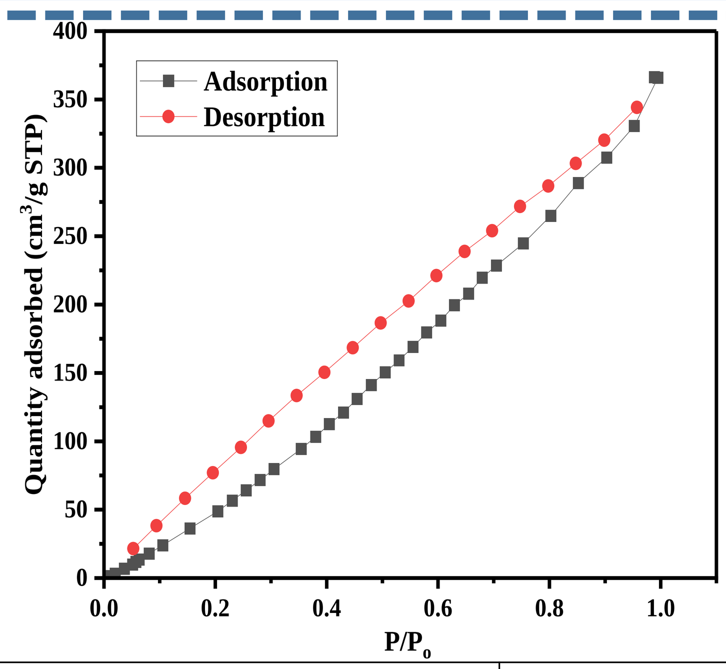
Characterization of the extract

- The IC50 for the tea waste extract is 65.23 µg/ml, compared to 11.60 µg/ml for ascorbic acid.
- HEK 293 cell viability stayed over 90% across all conditions, showing no significant cytotoxic differences between experimental and control groups, indicating the tea waste extract's safety at tested levels.



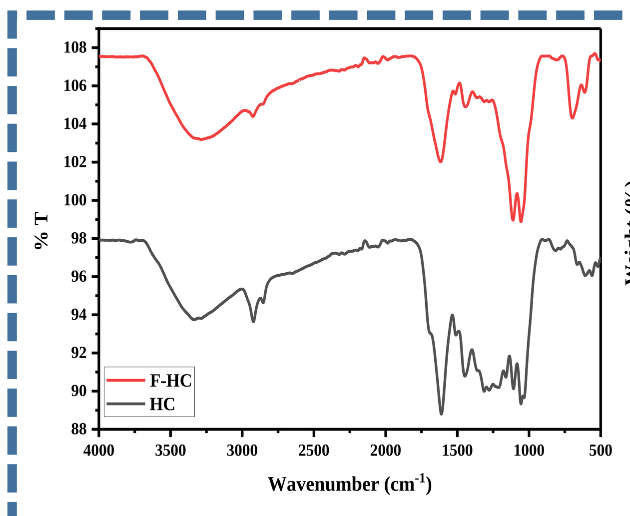


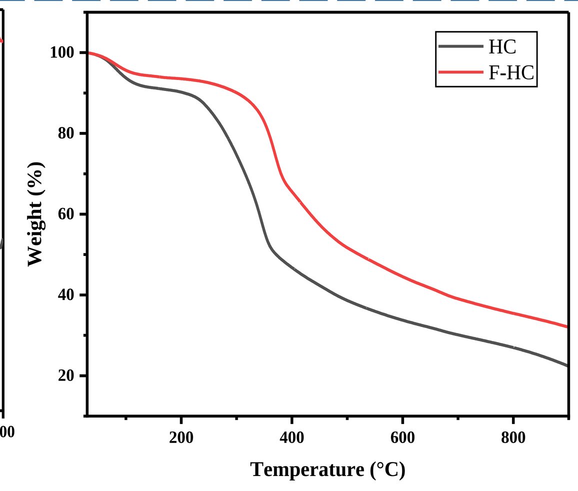
Characterization of hydrochar

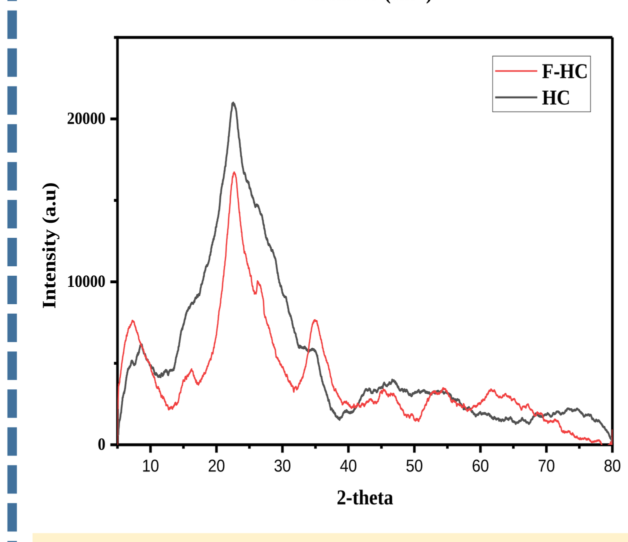


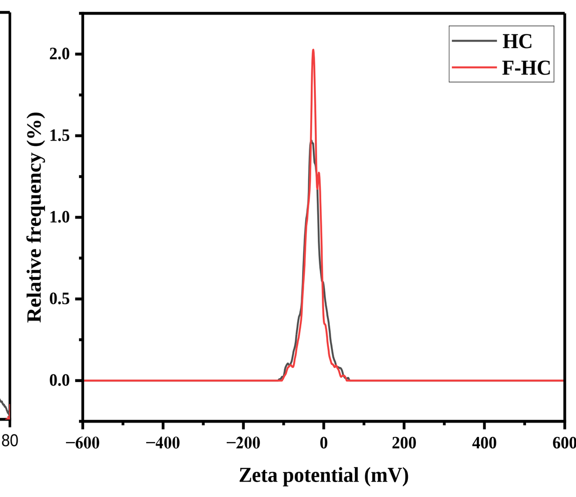
Average pore diameter	3.60919 nm
BET Surface area	627.309 m²/g
Total pore volume	0.566 cc/g
Isotherm type	III
Hysteresis loop type	III

FTIR, XRD, TGA and Zeta potential



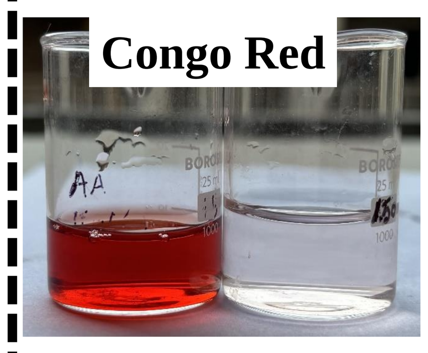




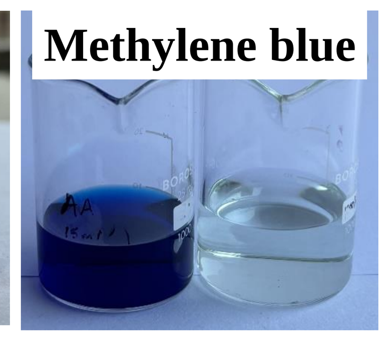


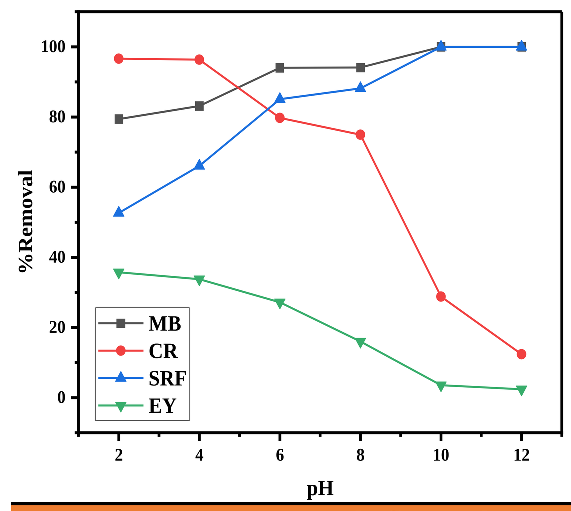
IR spectroscopy indicates only minor alterations in the OH, CH, and C=O functional groups, yet substantial changes are observed in the NO2 and CN stretches, suggesting modifications in the interactions of nitro and nitrile groups. XRD analysis of both HC and F-HC samples demonstrates the presence of similar amorphous carbon phases, with distinctions in crystallinity and peak intensities that imply variations in crystallite sizes and lattice strain. Furthermore, zeta potential measurements reveal values of -30.3 mV for HC and -24.5 mV for activated HC, indicating a shift in surface charge that could impact the interaction dynamics with surrounding molecules.

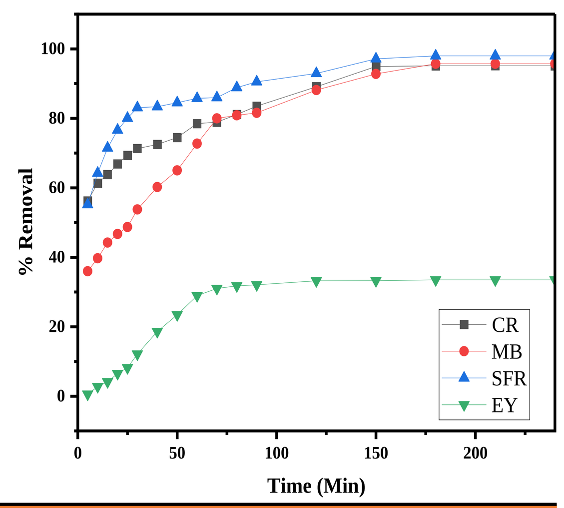
Dye adsorption


Congo Red


Safranin


Methylene blue





	Pseudo-first-order			Pseudo-second-order		
Dye	q_e (mg g^{-1})	K_1 (min−1)	R^2	q_e (mg g^{-1})	K_2 (min−1)	R^2
MB	15.927	0.013	0.965	26.469	0.0015	0.994
CR	17.772	0.003	0.912	24.950	0.0032	0.996
SAF	9.487	0.241	0.912	24.752	0.006	0.99
EY	30.895	0.00123	0.643	20.445	0.0002	0.222

The adsorption study indicates that all observed adsorption behavior adheres to the Langmuir adsorption isotherm, suggesting a monolayer adsorption process with uniform energy distribution across the adsorbent surface.

Summary

- **Optimal Extraction:** Efficiently extracted polyphenols from tea waste to maximize yield.
- **Hydrochar Production:** Converted residue to hydrochar, enhanced via Fenton oxidation.
- **Dye Adsorption:** Employed activated hydrochar for effective dye adsorption.
- **Sustainability Impact:** Transformed tea waste into valuable products, promoting environmental sustainability.

References

Debnath, B., Haldar, D., & Purkait, M. K. (2021). Potential and sustainable utilization of tea waste: A review on present status and future trends. *Journal of Environmental Chemical Engineering*, *9*(5), 106179.