

Abstract

Acacia mearnsii is an underutilized yet rich reservoir of bioactive phytochemicals with demonstrated corrosion inhibition efficacy, therapeutic potential, and extensive industrial applications. Its valorisation represents a significant step toward sustainable resource utilization and circular bioeconomy. This study integrates Adaptive Neuro Fuzzy Inference System (ANFIS) and Response Surface Methodology (RSM) within an advanced comparative modelling framework to optimize the sustainable recovery of these compounds from *Acacia mearnsii* bark using microwave-assisted extraction (MAE). Critical process variables, namely extraction time (2–10 min), temperature (30–70 °C), solid-to-solvent ratio (0.075–0.2 g/mL), and microwave power (150–350 W), were systematically evaluated using the Sugeno-type ANFIS model and Central Composite Design (CCD) within Response Surface Methodology (RSM). The coefficients of determination (R^2) for the RSM model (TPC: 0.9938; Y_{ex} : 0.9847) and the ANFIS model (TPC: 0.9981; Y_{ex} : 0.9935) indicated excellent predictive performance. The optimal conditions for maximum recoveries of total phenolic content (TPC: 85.45 mg GAE/g) and extraction yield (Y_{ex} : 21.040 %) were an extraction time of 6.192 min, temperature of 49.372 °C, solid-to-solvent ratio of 0.174 g/mL, and microwave power of 220.39 W, achieving an overall desirability of 0.990. GC–MS profiling revealed 21 bioactive constituents, confirming the phytochemical richness and renewable potential of *Acacia mearnsii* bark. This study establishes MAE combined with machine learning optimization as a green and highly efficient strategy for bioactive recovery, enabling transformative applications in food, pharmaceutical, and cosmetic industries.