



13-14 November 2025



Design, Synthesis, and Antioxidant Evaluation of Novel Curcumin Analogues for Food-Related Applications

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Abstract: We successfully synthesized two new asymmetrical curcumin analogues in their flavylum form, characterized using 1D and 2D NMR spectroscopy and mass spectroscopy. Their pH-dependent behaviour was investigated through UV-Vis spectroscopy, and antioxidant activity was assessed via the DPPH assay. The results validate the successful synthesis of these compounds and provide insights into their chemical stability and radical scavenging activity. These analogues exhibit significant potential for applications in the food industry due to their enhanced stability and functional properties.

• Introduction

Curcumin — that bright yellow spice that gives flavor and color to food, it is a natural polyphenol extracted from turmeric. It has remarkable antioxidant and anti-inflammatory properties and is widely used in traditional medicine and as a natural food colorant. However, its low solubility and poor bioavailability limit its applications — both in medicine and food systems. Therefore, our goal was to design and synthesize new analogues that could overcome these drawbacks.

• Aim of the study

This study aimed to design and synthesize novel curcumin analogues with enhanced stability and strong antioxidant activity. Due to their pH-dependent optical properties and high radical scavenging capacity, these compounds may serve as dual-function smart materials — acting both as antioxidants and as color indicators in active packaging systems designed to extend food shelf life.

• Material and method

1. The **synthesis** of the analogues followed a two-step Claisen-Schmidt condensation:
Step I (basic medium): substituted benzaldehydes with cyclohexanone in NaOH solution (4%, 24 h, r.t.), yielding the intermediate chalcone-type compound.
Step II (acidic gaseous medium): The intermediate was exposed to HCl gas with another aldehyde (4 h, r.t.), leading to cyclization and formation of the flavylum cation form of the final analogues. Yields: AM1-B (47.5%) and AM1-C (61.1%).

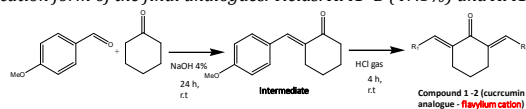


Fig. 1 Simplified Reaction Scheme

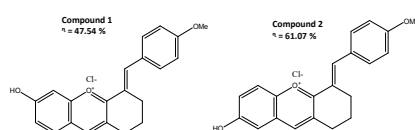


Fig. 2 Synthesized Compounds

2. Characterization

The structures were confirmed by 1D and 2D NMR, also by high-resolution (12,000) mass spectrometry in ESI mode ($m/z = 319.13235$ for AM1-B and 319.17203 for AM1-C).

3. **Antioxidant capacity** was determined by the DPPH radical scavenging assay. The decrease in absorbance at 517 nm was monitored, and IC_{50} values were calculated as indicators of radical scavenging efficiency.



• Results and discussions

Both analogues preserved the curcumin chromophore but showed distinct pH-dependent optical behavior. In acidic medium, an absorption band at 520 nm indicated the flavylum cation and a visible red color. With increasing pH (1 → 13), the color shifted from red to yellow, reflecting deprotonation and formation of neutral or chalcone-like species.

For AM1-C, the disappearance of the 520 nm band confirmed the loss of the flavylum form. These transitions demonstrate a reversible acid-base equilibrium.

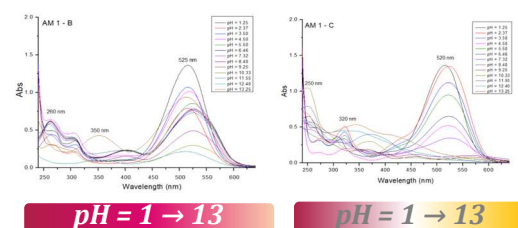


Fig. UV - VIS spectra



Both analogues showed remarkable antioxidant activity, with AM1-C ($IC_{50} = 21.8 \mu\text{g/mL}$) exhibiting a very strong effect close to ascorbic acid ($8.4 \mu\text{g/mL}$), while AM1-B ($63.7 \mu\text{g/mL}$) also demonstrated notable radical scavenging capacity.

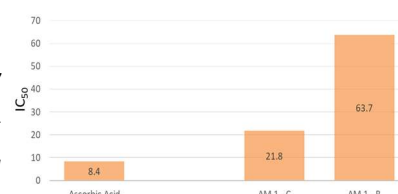


Table.1 IC_{50} - antioxidant activity

• Conclusions

- ✓ Two new curcumin analogues have been successfully synthesized.
- ✓ The flavylum form proved reversible color transitions under different pH conditions. UV-Vis spectra confirmed the stability of colored forms across a wide pH range.
- ✓ AM1-C showed a lower IC_{50} value ($21.8 \mu\text{g/mL}$) and can be placed like a very strong antioxidant and AM1-B ($63.7 \mu\text{g/mL}$) as a strong one.
- ✓ These findings support their potential use as antioxidants and colorants in

• References

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Acknowledgement: The authors acknowledge the support of "Coriolan Drăgulescu" Institute of Chemistry, Timișoara, Program 4.

