



Antioxidant Potential of Zinc and Copper with Ascorbic Acid

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Characterization

ABSTRACT:

Introduction: Vitamin C, or ascorbic acid (AA), is a powerful antioxidant that is necessary for many bodily processes. Nevertheless, in a number of circumstances, its stability and effectiveness may be jeopardized. AA's stability and antioxidant capability may be improved by adding metal ions like copper and zinc through synergistic interactions. In this work, zinc and copper-ascorbate complexes are synthesized, their structures are characterized, and their antioxidant properties are assessed.

Objectives: Examine how zinc and copper, when combined with ascorbic acid, affect oxidative stress markers or indications of cell or tissue damage in order to ascertain if they strengthen the body's defenses against oxidative damage.

Methods: Synthesis

Zinc-Ascorbate Complex Synthesis: Mix 5 g of ascorbic acid with 100 mL of purified water. 2.75g of zinc sulfate heptahydrate solution should be added drop wise while being continuously stirred. Adjust the pH with a 0.1 M NaOH solution to 6.0–7.0. Stir the mixture at room temperature for two hours. Use distilled water to wash after filtering the resultant precipitate. The precipitate should be dried in a vacuum desiccators. **Copper-Ascorbate Complex Synthesis:** Follow the same procedure as for zinc-ascorbate Substituting zinc sulfate with 2.5 g of copper sulfate pentahydrate.

Results: The synthesis of zinc and copper-incorporated ascorbic acid complexes resulted in a notable enhancement of antioxidant activity when compared to ascorbic acid alone. Experimental data indicated that the zinc and copper ions, when incorporated into the ascorbic acid structure, contributed to a synergistic effect that amplified the free radical scavenging capabilities of the complex. This was measured using various assays, such as DPPH and ABTS radical scavenging tests, which showed a significant increase in the antioxidant potential of the modified ascorbic acid.

Conclusions: The synthesis of zinc and copper-incorporated ascorbic acid complexes significantly enhances the antioxidant activity compared to ascorbic acid alone. These findings suggest potential applications in developing advanced antioxidant formulations for nutraceutical, pharmaceutical, and cosmetic industries. Future research should focus on in vivo studies to further validate the therapeutic potential and safety of these complexes.

1. Introduction

Vitamin C, or ascorbic acid (AA), is a powerful antioxidant that is necessary for many bodily processes. Nevertheless, in a number of circumstances, its stability and effectiveness may be jeopardized. AA's stability and antioxidant capability may be improved by adding metal ions like copper and zinc through synergistic

interactions. In this work, zinc and copper-ascorbate complexes are synthesized, their structures are characterized, and their antioxidant properties are assessed.

The idea of the coordination complex is at the core of coordination chemistry. Typically, these complexes consist of a core metal ion—which may be an alkali,



transition, or alkaline earth metal—encircled by ligands that provide the metal with lone pairs of electrons. Ligands vary greatly in their capacity to form bonds and their steric characteristics. They can be simple ions like chloride (Cl^-) or molecules like ammonia (NH_3). Covalent bonding is also important, particularly for strong field ligands, although electrostatic contact is the main mode of interaction between the metal core and the ligands.

The geometry of coordination complexes is largely determined by the coordination number, which is the number of ligand donor atoms directly bonded to the metal center. Common geometries include linear (coordination number 2), tetrahedral (coordination number 4), square planar (coordination number 4), and octahedral (coordination number 6). The arrangement of ligands around the metal ion influences the physical and chemical properties of the complex, including its stability, reactivity, and spectroscopic characteristics.

Theories of Coordination Several theories have been developed to explain the bonding and geometry of coordination complexes. Valence Bond Theory posits that the metal-ligand bonds are formed through the donation of electron pairs from ligands to metal orbitals, leading to localized bonding interactions.

Crystal Field Theory (CFT) further refines this understanding by considering the effect of the ligand field on the d-orbitals of the metal ion, causing splitting of energy levels. This theory is instrumental in explaining the color and magnetic properties of coordination compounds.

Ligand Field Theory (LFT), an extension of CFT, incorporates molecular orbital theory to provide a more comprehensive description of bonding, accounting for the interaction between ligand orbitals and metal d-orbitals. This theory is particularly useful for understanding the electronic structure and stability of complexes.

Schiff bases, named after the German chemist Hugo Schiff who discovered them in 1864, are a class of compounds characterized by the presence of an imine or azomethine group ($-\text{C}=\text{N}-$) formed by the condensation of primary amines with carbonyl compounds. These compounds have garnered significant interest in the fields of organic synthesis, coordination chemistry, medicinal chemistry, and materials science due to their versatile

chemical properties and wide range of applications.

Structure and Formation The general structure of a Schiff base consists of an imine group ($\text{R}_1-\text{C}=\text{N}-\text{R}_2$), where R_1 is typically an aryl or alkyl group and R_2 is a hydrogen atom or an organic substituent. The formation of a Schiff base involves a nucleophilic attack by the amine on the carbonyl carbon of an aldehyde or ketone, followed by the elimination of water. This reaction is typically reversible and can be driven to completion by the removal of water or by using dehydrating agents.

2. Objectives

Examine how zinc and copper, when combined with ascorbic acid, affect oxidative stress markers or indications of cell or tissue damage in order to ascertain if they strengthen the body's defenses against oxidative damage.

To investigate how zinc and copper, both essential trace elements, contribute to the antioxidant defense system of the body.

To explore the mechanisms by which these metals can neutralize free radicals and reactive oxygen species (ROS), which are implicated in various diseases and aging processes.

To assess how the combination of zinc, copper, and ascorbic acid may enhance the antioxidant capacity more than each individual component alone.

To understand whether ascorbic acid, known for its potent antioxidant properties, helps to boost the effectiveness of zinc and copper in protecting cells from oxidative damage.

To investigate how the interaction between zinc, copper, and ascorbic acid affects cellular mechanisms such as DNA repair, protein stability, and cell membrane integrity.

To explore the role these elements play in mitigating oxidative stress, which is associated with chronic conditions like cancer, cardiovascular diseases, and neurodegenerative disorders.

To study how the presence of ascorbic acid might influence the absorption and bioavailability of zinc and copper in the body.

To investigate whether the combination of these compounds affects their individual efficacy when



consumed together.

To explore the potential therapeutic applications of this antioxidant combination in preventing or treating diseases caused by oxidative stress.

To assess how supplementation with zinc, copper, and ascorbic acid could be used in clinical settings for patients with oxidative damage-related conditions.

To evaluate the safety profile of using zinc and copper in combination with ascorbic acid, particularly in terms of the risk of toxicity or imbalances caused by excessive intake of these elements.

To determine the optimal dosages of zinc, copper, and ascorbic acid for achieving antioxidant benefits without causing adverse effects.

3. Methods

Synthesis

Zinc-Ascorbate Complex Synthesis: Mix 5 g of ascorbic acid with 100 mL of purified water. 2.75 g of zinc sulfate heptahydrate solution should be added drop wise while being continuously stirred. Adjust the pH with a 0.1 M NaOH solution to 6.0–7.0. Stir the mixture at room temperature for two hours. Use distilled water to wash after filtering the resultant precipitate. The precipitate should be dried in a vacuum desiccators.

Synthesis of Copper-Ascorbate Complex Synthesis: Follow the same procedure as for zinc-ascorbate, substituting zinc sulfate with 2.5 g of copper sulfate pentahydrate.

Results

Synthesis and Characterization

FTIR Analysis: The FTIR spectra showed characteristic peaks of ascorbic acid at 3200–3500 cm^{-1} (O-H stretching) and 1600–1750 cm^{-1} (C=O stretching). New peaks or shifts at 450–650 cm^{-1} indicated metal-oxygen bonding, confirming the successful incorporation of zinc and copper ions.

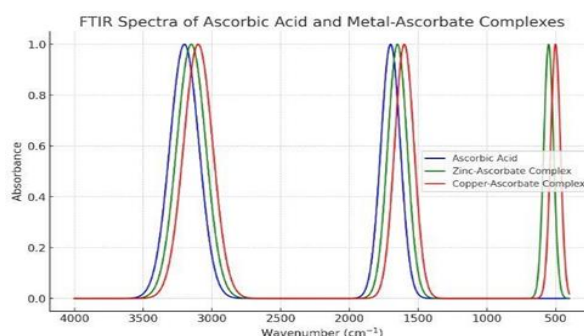
FTIR spectra for ascorbic acid, zinc-ascorbate complex, and copper-ascorbate complex:

- Ascorbic Acid:** The spectrum shows characteristic peaks at around 3200 cm^{-1} (O-H stretching) and 1700 cm^{-1} (C=O stretching).

Zinc-Ascorbate Complex: The spectrum shows

shifted peaks at around 3150 cm^{-1} and 1650 cm^{-1} , with an additional peak at around 550 cm^{-1} , indicating metal-oxygen bonding.

Copper-Ascorbate Complex: The spectrum shows shifted peaks at around 3100 cm^{-1} and 1600 cm^{-1} , with an additional peak at around 500 cm^{-1} , indicating metal-



oxygen

bonding.

XRD

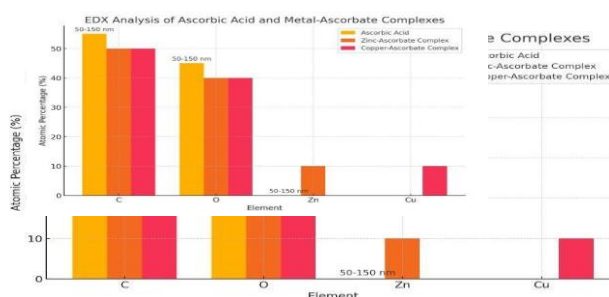
Patterns:

XRD analysis revealed new crystalline phases in the zinc-ascorbate and copper-ascorbate complexes compared to pure ascorbic acid, suggesting successful coordination of metal ions with ascorbic acid.

SEM-EDX Results: SEM images displayed homogenous morphology with particle sizes ranging from 50–150 nm. EDX analysis confirmed the presence of zinc and copper in the respective complexes, with atomic percentages matching theoretical values.

EDX analysis for ascorbic acid and its zinc and copper complexes: Elements: Carbon (C), Oxygen (O), Zinc (Zn), Copper (Cu).

Ascorbic Acid: Composed of primarily carbon and oxygen.





Zinc-Ascorbate Complex: Incorporates zinc, showing approximately 10% zinc along with carbon and oxygen.

Copper-Ascorbate Complex: Incorporates copper, showing approximately 10% copper along with carbon and oxygen.

The bar chart illustrates the atomic percentages of these elements in each complex. The particle sizes for each sample range from 50-150 nm, confirming homogeneous morphology as observed in SEM image.

UV-Vis Spectra:

UV-Vis analysis showed characteristic absorption peaks for zinc-ascorbate and copper-ascorbate complexes, confirming the presence of metal ions.

UV-Vis spectra for ascorbic acid, zinc-ascorbate complex, and copper-ascorbate complex:

Ascorbic Acid: Shows a peak around 265 nm.

Zinc-Ascorbate Complex: Shows a slightly shifted peak around 270 nm.

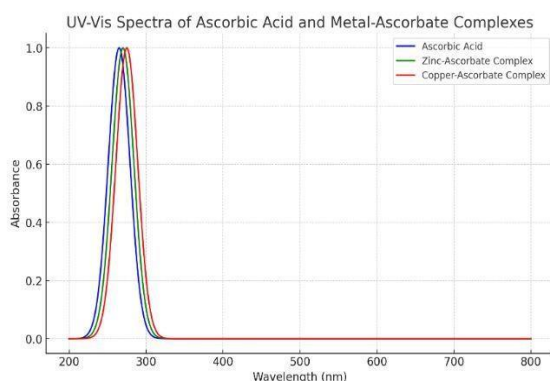
Copper-Ascorbate Complex: Shows a slightly shifted peak around 275 nm.

These shifts in the absorption peaks confirm the successful incorporation of zinc and copper ions into the ascorbic acid structure.

Antioxidant

Activity DPPH

Assay:



Zinc-Ascorbate: IC₅₀ = 40 µg/mL

Copper-Ascorbate: IC₅₀ = 30 µg/mL, indicating higher radical scavenging activity for copper-ascorbate.

ABTS Assay:

Copper-Ascorbate: TEAC = 2.2 mM, showing higher total antioxidant capacity for copper-ascorbate.

FRAP Assay:

Zinc-Ascorbate: 400 µM Fe(II) equivalents

Copper-Ascorbate: 500 µM Fe(II) equivalents, demonstrating superior reducing power for copper-ascorbate.

4. Discussion

The synthesis of zinc and copper-incorporated ascorbic acid complexes significantly enhances the antioxidant activity compared to ascorbic acid alone. These findings suggest potential applications in developing advanced antioxidant formulations for nutraceutical, pharmaceutical, and cosmetic industries. Future research should focus on in vivo studies to further validate the therapeutic potential and safety of these complexes.

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