Use of the compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one) as a ligand complex formation by copper (II)

Itnawita*, Zamri Adela, Ganis Fia Kartika, Sofia Anita, T. Abu Hanifah, G.A. Guntur and U. Shyfaa

*aFaculty of Mathematics and Natural Sciences, University of Riau, Pekanbaru, Indonesia

ABSTRACT

Flavanol compounds are chalcone derivatives, generally found in hydroxy substituted forms that can act as ligands. Hydroxy-substituted flavonols are found in many plants but in very small amounts. In order to enrich and expand the use of this compound as a ligand, synthetic methods were carried out through structural variations, one of which was by substitution using chloride and then the compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one) was obtained. In this research, the study was conducted using the compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one) as a ligand for complex formation with copper (II). From the results of the study, the mole ratio of the ligand with copper (II) metal was 2:1, pH 7.01 with a complex stability time of 15-25 minutes. The complex formed is bright yellow in color and soluble in chloroform. From the characterization of the resulted complex, it was appeared that Cu-flavonol chloride with UV-Vis spectrophotometer showed maximum absorption at wavelengths 273 and 429 indicating the presence of benzoyl and cinnamoyl peaks, with FT-IR showing the wave number 1545cm$^{-1}$ indicating the presence of Cu=O-Cu bonds and absorption at 682 cm$^{-1}$ indicating the presence of Cu-O bonds.

Keywords: Flavonol Chloride, Chalcone, Complex, Ligand

1. Introduction

Flavanols are chalcone-derived compounds known as secondary metabolites and belong to the flavonoid class. In plants, these compounds are generally found in a hydroxy-substituted form, although in very small amounts. The presence of free electrons from the 5-hydroxy and 4-ketone functional groups substituted in the flavonol structure plays a very important role in bioactivity, such as antibacterial and cardiovascular effects and can act as ligands in the formation of complex compounds with metals. Several studies have reported the synthesizing of complex compounds from several hydroxy substituted flavonol compounds with metals such as metal ions Cr, Tb, Rh, Mg, Zn and Fe. To enrich and expand the use of this compound as a ligand, synthesis was carried out through structural variations, one of which was by substitution using chloride. The presence of chloride is expected to affect the induction effect so that there is a shift in the electron density of the functional group and the level of stability of the complex.

Structural variations with chloride substitution have been successfully carried out through the Flyn-Algar-Oyamada (FAO) reaction of the compound 2'-hydroxychalcone, (E)-3-(4-chlorophenyl)-1-(2-hydroxyphenyl)prop-2-en-1-on with H$_2$O$_2$ in an alkaline solution produced a new compound in the form of a chloride substituted flavonol, namely the compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one). From a preliminary test using flavonol-chloride as a ligand for several central ions, the complex with Cu(II) showed a distinctive color change compared to using other transition metals. According to Suciningrum, copper as the central atom has the greatest complex ion stability compared to other fourth period transition metals. As research by Říha et al. has synthesized metal complex compounds Cu(II) with 3-hydroxyflavone ligands showed that flavonols as bidentate ligands were formed with a stoichiometric ratio of 2:1 in the pH range 5.5 – 7.5.
Heterocyclic compounds constitute the largest diversity of organic molecules of chemical, biomedical, and industrial significance. For the formation of Cu complexes with flavonol chlorides, it is necessary to know the mole ratio of ligands and metal ions, complex stability time and optimal environmental pH. pH plays an important role in complex formation because, in high acidity environmental conditions there will be a decrease in the ability of the ligands to interact with metal ions, because the ligand is difficult to deprotonize. On the other hand, in an alkaline environment there will be a lot of hydroxy ions which will deprotonate the ligand so that the complex is easier to form and more stable.

2. Research Methods

2.1. Materials

The tools used in this study were a microwave (Samsung ME109F), UV-Vis spectrophotometer (Agilent Technologies, Cary 60), FT-IR spectrophotometer (Shimadzu, IR Prestige-21), HPLC (Shimadzu LC Solution column type Shim-pack VP-ODS with length and diameter of 150 x 4.6 mm), GF254 silica TLC plate, UV lamp (254 and 366 nm), vacuum pump (ABM type 4EK F6 3CX-4) and synthesis equipment commonly used in laboratories. The materials used in this study were 2-hydroxy acetophenone, 4-chlorobenzaldehyde, copper(II) sulfate pentahydrate, KOH, HCl, 30% H₂O₂, aqua DM, and various organic solvents.

2.2. Synthesis of compounds (2-(4-chloro phenyl)-3-hydroxy-4H-chromen-4-one)

A total of 0.5 mmol of 2'-hydroxychalcone compound was dissolved in 5 mL of ethanol and 1 mL of 3N KOH was added. The mixture was cooled to 10°C. Then add 0.25 mL of 30% H₂O₂ to the mixture and irradiated with a microwave at 180W for 2 minutes. Every 30 seconds the reaction was tested by TLC. After the reaction was complete, 5 mL of 10% cold HCl was added dropwise to the mixture until a precipitate was formed. The precipitate was filtered using Whatman 42 filter paper. Then it was washed with cold distilled water and n-hexane. The solids were dried to obtain pure chloride substituted flavonols tested based on TLC analysis, melting point and HPLC.

2.3. Synthesis of Cu(II)-(2-(4-chlorophenyl)-3-hydroxy-4-chromene-4-one complexes)

A total of 10 mL (1 mmol) of compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one) in ethanol solvent was added to Erlenmeyer. Then slowly add 10 ml of copper sulfate pentahydrate solution (0.5 mmol) and stir for 1.5 hours at room temperature, the precipitate formed is filtered using filter paper with the help of a vacuum pipe. The precipitate of complex compounds on filter paper was washed with ethanol solvent: water (3:1).

2.4. Determination of the optimum pH for the synthesis of copper (II)-flavonol chloride complex compounds

A total of 10 mL of 2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one with a concentration of 10⁻³ M was put into an erlenmeyer. Slowly add 5 mL of 10⁻³ M solution of copper (II) sulfate pentahydrate at pH 4.03 and add 5 mL of chloroform, stirring the solution using a magnetic stirrer at 300 rpm for 20 minutes at room temperature. The chloroform solvent was separated from the mixture using a separating funnel and collected into a vial. Then the solution was placed in a cleaned cuvette and its absorbance was measured with a UV-Vis spectrophotometer using a wavelength of 429 nm against a chloroform blank. Do the same for variations in pH 5.00; 6.01; 7.01 and 8.08.

2.5. Determination of stability time of copper(II)-flavonol chloride complex

A total of 10 mL of 2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one with a concentration of 10⁻³ M was put into an erlenmeyer. Slowly add 5 mL of 10⁻³ M copper (II) sulfate pentahydrate solution at optimal pH and add 5 mL of chloroform, stirring the solution using a magnetic stirrer at 300 rpm for 20 minutes at room temperature. The chloroform solvent was separated from the mixture using a separating funnel and collected into a vial. Then the solution was placed in a cleaned cuvette and its absorbance was measured with a UV-Vis spectrophotometer using a wavelength of 429 nm every 5 minutes for 2 hours.

3. Results

3.1. Synthesis of compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromen-4-one)

The formation of the compound (2-(4-chloro phenyl)-3-hydroxy-4H-chromen-4-one), begins with the elimination of hydrogen at the carbon á position of the 2'-hydroxyacetophenone compound in an alkaline solution. The elimination of hydrogen at this position occurs due to the absorption of OH- ions from the base which acts as a nucleophile to form phenoxide ions. The reaction for the formation of chloride substituted flavonols can be seen in Fig. 1. The purity of the compound (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one) was proven by TLC test where Rf = 0.54 while Rf of 2'-hydroxychalcone = 0.86. This shows that flavonol chloride compounds have been formed which have greater polarity than
2'-hydroxychalcone compounds. Melting point test obtained temperature intervals that are less than two, namely between 157 – 159°C. The functional group test with FT-IR obtained several types of vibrations, including C-Cl at wave number 760 cm⁻¹, C-O at 1108 cm⁻¹, C=C at 1560 cm⁻¹, aromatic C-H at 3109 cm⁻¹ and O-H at 3284 cm⁻¹. Meanwhile, the characterization using UV-Vis spectrophotometry showed that there were 2 maximum peaks, namely the benzoyl and cinnamyl peaks contained in the structure of the compound at a wavelength of 243nm, 344nm (Figure 2). Ensafi et al., said that flavonol group compounds will give 2 maximum peaks in their electronic spectrum caused by the electron transition (π – π*).22

![Fig. 1. Reaction for formation of chloride-substituted flavonols](image)

3.2. Synthesis of Cu(II) - (2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one Complex)

The formation of complex compounds with flavonol ligands occurs when the occupied orbitals of the flavonol ligands hybridize (overlap) to the empty copper (II) metal ion orbitals to form sp³d² hybridization. Based on the valence bond theory, the sp³d² hybridization of the complex formed is an outer sp³d² orbital so that it is possible that the complex formed is relatively unstable. Copper(II) metal can form a d⁹ system complex with a distorted octahedral geometry due to the Jahn Teller stabilization energy. This distorted octahedral geometry is more stable than the copper(II) complex tetrahedral geometry. This distorted geometric shape also results in only 2 substituted flavonol ligands (bidentate ligands) because there are 2 lone electron pair donor sites, namely the 4 keto and 3 hydroxy sites. The hydroxy site is a stronger nucleophile than the chloride substituted at the para position.23,24 This causes the formation of complex compounds to be more likely to occur in the hydroxyl group than chloride, so that it is more difficult for chloride to donate its electron pair, meaning that the substitution of chloride does not specifically affect the formation of complexes with the central Cu(II) atom.

![Fig. 2. Peak shift in the benzoyl system and sinamoil](image)

3.3. Complex characterization of Cu(II)-(2-(4-chlorophenyl)-3-hydroxy-4H-chromene-4-one)

Based on solubility, Cu-flavonoid chloride complex is slightly polar and more soluble in cloform. From the FT-IR spectra of complex compounds, the coordination covalent bonds of complex compounds between C=O in flavonols and Cu metal (C=O-Cu bonds) appear indicated by the appearance of an absorption band of 1545 cm⁻¹. The formation of this
Coordination bond causes the vibration of the C=O bond in the organic molecule. The absorption band of the C=O group in the complex changed to a wave number of 1605 cm\(^{-1}\). In addition, the formation of Cu-O bonds was indicated by the appearance of absorption at a wave number of 680 cm\(^{-1}\), besides that the formation of complexes was also indicated by the occurrence of a bathochromic red shift of the cinnamoyl system from 346 nm to 429 nm. This is in accordance with the results of research Souza et al. have synthesized a complex of Cu with 3-hydroxyflavones to produce a spectrum, FT-IR at 610 cm\(^{-1}\) band and a bathochromic shift of the cinnamoyl peak at 343 nm to 359 nm. The FT-IR spectrum is shown in Fig. 3.\(^{25}\)

![Figure 3](image)

**Fig. 3.** FT-IR spectrum of flavonol chloride and Cu(II) flavonol chloride compounds at wave numbers 1750-450 cm\(^{-1}\)

### 3.4. Determination of the optimum pH of the Cu(II)-flavonol chloride complex

In general, Cu(II) complex formation reactions can occur in the pH range of 4 – 7. Říha et al., synthesized 3-hydroxyflavones to form complex compounds with Cu(II) metal showing flavonols as bidentate ligands with a stoichiometric ratio of 2:1 in the pH range of 5.5 – 7.5.\(^{13}\) From the research results, it can be seen that the optimal pH is reached at pH 7.01. Under acidic conditions (pH 4 and 5) a shift in equilibrium occurs due to protonated flavonols so that the equilibrium shifts towards the reactants. Protonation of flavonol compounds will reduce its ability as a ligand to donate electron pairs. This is because protonation of the carbonyl group will form a positive synthone (lack of electrons) which will tend to like nucleophiles and there is a steric hindrance. The steric hindrance at this site makes it difficult for copper (II) metal to interact with its electron pair donor group. It is also possible that there is complex formation at the chloride B ring site. However, the complex at the chloride site has a lower level of stability. The low stability is due to the presence of chloride with a higher electronegativity than oxygen so that the distribution of electrons in metallic bonds with ligands is uneven. Under alkaline conditions (pH 8), Cu(OH)\(_2\) tends to form, causing the reaction equilibrium of complex compounds to shift towards the reactants (Fig. 4).

![Figure 4](image)

**Fig. 4.** The results of the measurement of the absorbance of the synthesis of complex compounds in various pHs with a synthesis ratio of 2:1
4. Conclusion

Based on the results of the research, it can be concluded that the synthesis of the Cu(II)-flavonol chloride complex showed an optimal mole ratio of 2:1 with a stability period of 25-35 minutes at pH 7.01 (neutral). The Cu(II) flavonoid chloride complex is yellow in color and is well soluble in chloroform. The results of the characterization of the Cu(II)-flavonol chloride complex showed the presence of Cu-O bonds at 682 cm$^{-1}$ and C=O-Cu bonds absorption band at 1545 cm$^{-1}$.

References

1. Farhan S. A. (2013) Study on the interaction of copper (II) complex of morin and its antimicrobial effect, Int. J. Chem. Sci., 11 (3) 1247-1255.
2. Jadhav S. B., Bagul K. R., Bagul P. R., and Gaikwad K. V. (2008) Synthesis of some novel flavonol derivatives and its microbial activity, Orien. J.Chem., 24 (2) 583-588.
3. Alexiou A. D., Silva D. D., Romoff P., and Ferreira M. J. (2016) Tris (3, 7-dihydroxyflavonolate-κO3, O4) chromium (III) Complex, Molbank, 2016 (1) M886.
4. Dolatabadi J. E. N., Mokhtarzadeh A., Ghareghorani S. M., and Dehghan G. (2014) Synthesis, characterization and antioxidant property of quercetin-Tb (III) complex, Adv. pharm. bull., 4 (2) 101-104.
5. Kandiller W., Balsano M., Meier S. M., Jungwirth U., Göschl S., Roller A., ... and Hartinger C. G. (2013) Organometallic anticancer complexes of lapachol: metal centre-dependent formation of reactive oxygen species and correlation with cytotoxicity, Chem. Comm., 49 (32) 3348-3350.
6. Destria M., Widiyantoro A., and Jayuska A. (2019) Senyawa Flavonoid dari Fraksi Diklorometana Buah Mangga Golek (Mangifera spp.) sebagai pengikis Fe2+, Jurnal Kimia Khatulistiwa, 8 (1).
7. Abdelhamid A. A, Salama K. S. M., Elsayed A. M., Gad M. A., and El-Remaily M. A. A. (2022) Synthesis and Toxicological effect of some new pyrrole derivatives as prospective insecticidal agents against the cotton leafworm, Spodoptera littoralis (Boisd.), Biotech. rep., 24 (2019) 394-401.
8. Ikhtiarudin I., Frimayanti N., Teruna H. Y., and Zamri A. (2017) Microwave-Assisted Synthesis, Molecular Docking Study and In Vitro Evaluation of Halogen Substituted Flavonols Against P388 Murine Leukemia Cells, App. Sci. Tech., 1 (1) 375-381.
9. Łapczuk-Krygier, A., Korotaev, V. Y., Barkov, A. Y., Sosnovskikh, V. Y., Jasińska, E., and Jasiński, R. (2014) A DFT computational study on the molecular mechanism of the nitro group migration in the product derived from 3-nitro-2-(trifluoromethyl)-2H-chromene and 2-(1-phenylpropylidene) malononitrile, J. Fluorine Chem., 168, 236-239.
10. Fernando F. (2017) Sintesis dan karakterisasi senyawa kompleks tembaga (II) – flavonolat tersubstitusi klorida, Universitas Riau, Pekanbaru.
11. Suciningrum E. (2011) Sintesis dan Karakterisasi Kompleks Tembaga (II) dengan Difenilamin, Universitas Sebelas Maret, Surakarta.
12. Říha M., Karlíčková J., Filipský T., Macákův K., Rocha L., Bovicelli P., ... and Mladěnka P. (2014) In vitro evaluation of copper-chelating properties of flavonoids, Rsc Advances, 4 (62) 32626-32638.
13. Elhady, O., Mansour, E., Elwassimy, M., Zawam, S., Drar, A., and Abdel-Raheem, S. (2022) Selective synthesis, characterization, and toxicological activity screening of some furan compounds as pesticidal agents, Curr. Chem. Lett., 11 (3) 285-290.
14. Tolba, M. S., Sayed, M., Kamal El-Dean, A. M., Hassanien, R., Abdel-Raheem Sh, A. A., and Ahmed, M. (2021) Design, synthesis and antimicrobial activity screening of some new thienopyrimidines, Org. Comm., 14 (4) 334-345.
15. Abdel-Raheem, S., El-Dean, A., Hassanien, R., El-Sayed, M., Abd-Ella, A., Zawam, S., and Tolba, M. (2022) Synthesis of new distyrylpyridine analogues bearing amide substructure as effective insecticidal agents, Curr. Chem. Lett., 11 (1) 23-28.
16. Abd-Raheem, S. A., El-Dean, A. M. K., Hassanien, R., El-Sayed, M. E., and Abd-Ella, A. A. (2021) Synthesis and characterization of some distyryl derivatives for agricultural uses, Eur. Chem. Bull., 10 (1) 35-38.
17. Tolba, M., El-Dean, A., Geies, A., Radwan, S., Zaki, R., Sayed, M., ... and Abdel-Raheem, S. (2022) An overview on synthesis and reactions of coumarin based compounds, Curr. Chem. Lett., 11 (1) 29-42.
18. Tolba, M., El-Dean, A., Ahmed, M., Hassanien, R., Sayed, M., Zaki, R., ... and Abdel-Raheem, S. (2022) Synthesis, reactions, and applications of pyrimidine derivatives, Curr. Chem. Lett., 11 (1) 121-138.
19. Abd-Ella, A., Metwally, S., El-Ossaily, Y., Elrazek, F., Aref, S., Naffea, Y., and Abdel-Raheem, S. (2022) A review on recent advances for the synthesis of bioactive pyrazolone and pyrazolidinedione derivatives, Curr. Chem. Lett., 11 (2) 157-172.
20. Abd-Raheem, S., El-Dean, A., Abd-Ella, A., Al-Taiфи, E., Hassanien, R., El-Sayed, M., ... and Bakhit, E. (2021) A concise review on some synthetic routes and applications of pyridine scaffold compounds, Curr. Chem. Lett., 10 (4) 337-362.
dihydroxynaphthalene-2, 7-disulfonic acid) film modified glassy carbon electrode, *J. Elect. Chem.*, 633 (1), 212-220.

23. Wade L. G. (2010). Reactions of Alcohols. *Organic Chem.*, 6, 494-495.

24. Hasan A., and Pandey L. M. (2018) Self-assembled monolayers in biomaterials, in: Narayan R. (Ed) *Nanobiomaterials* (pp. 137-178). Woodhead Publishing, Chambridge.

25. De Souza R. F., and De Giovani W. F. (2004) Antioxidant properties of complexes of flavonoids with metal ions. *Redox Report*, 9 (2), 97-104.

© 2022 by the authors; licensee Growing Science, Canada. This is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).