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Chelation of Toxic Tin(II) by Quercetin: A Spectroscopic Study

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Abstract- **Human diet has a variety of nutraceuticals including flavonoids like quercetin that can support our body even against toxic tin compounds. Therefore, chelation therapy is of great interest in modern medicine. Quercetin is well known as a protective antioxidant and free radical scavenger which shows various antioxidant properties after complexation with metals. In this research we studied the ability of quercetin to chelating the toxic tin in organic stannous chloride ($SnCl_2.2H_2O$) form. To access the more information on chelation, ^{1}H-NMR, IR and UV-visible spectroscopic studies were carried out.**

Keywords: Chelation therapy; Toxic Tin; Quercetin-Sn(II) complex; spectroscopy

I. INTRODUCTION

Flavonoids are polyphenolic compounds which found ubiquitously in human diet, such as fruits, vegetables and plant-derived beverages such as tea and red wine (1).

Flavonoids have a basic structure of (2-phenyl-benzo-γ-pyrones, Fig.1, a) mostly polyphenolic in nature. Flavonoids are important natural antioxidants and free radical scavengers, and most of them are strong metal chelators which can chelate many metal ions to form different complexes (2, 3). So that they play an important role in both the bioavailability for metal ions which are in trace levels in our body like Al(III) and the toxicity of a variety of toxic metals like Pb(II) (4) and Sn(II) (stannum) another toxic cation which is the aim of our work.

Tin compounds exist in two major groups of organotins and inorganic tin compounds. The chemical, physical, and biochemical properties and also toxicity of inorganic tin compounds differ dramatically from organotins, which are compounds with at least one tin-carbon bond (5). Although inorganic tin and its salts are not highly toxic due to their poor absorption but signs of inorganic tin poisoning in mammals include local effects such as vomiting, diarrhea, and eye and nose irritation. The major systemic effects include ataxia, paralysis, growth retardation, decreased hemoglobin levels, and at extremely high doses, testicular degeneration, pancreatic atrophy, and kidney necrosis (6). Concentrations of tin in most foods are usually less than 1 part per million (ppm), whereas in canned foods, especially those with an acidic pH, considerably higher levels, e.g., 100-500 ppm (0.01-0.05%) or more may be found. Various estimates of dietary tin intake have been reported ranging from about 200μg/day to 5.8-8.8 mg/day (7).

Quercetin is one of the effective metal chelators which possesses three possible chelating sites in competition: the 3-hydroxy-carbonyl, the 5-hydroxy-carbonyl, and the 3′,4′-dihydroxyl (catechol) groups (Fig.1,b). Complexation of metal cations by quercetin has already been reported for a great number of metals (Fe^{2+}, Fe^{3+}, Cu^{2+}, Zn^{2+}, Al^{3+}, Cr^{3+}, Pb^{2+}, $Co2^{+}$ and many other cations) and in these studies different stoichiometric ratios can be seen between different metals and quercetin as a ligand (8). The aim of this study was to investigate complex formation between quercetin and toxic tin, from chelation therapy point of view.

II. EXPERIMENTAL

A. Instruments and reagents

Spectroscopic study of quercetin and its metal complex was performed by using analytikjena UV-visible spectrophotometer specord 40 for obtaining UV spectra and Bruker Tensor 27 spectrophotometer for obtaining IR data. ^{1}H-NMR spectra were achieved using a Bruker 500 MHz spectrometer (Brucker, Rheinstetten, Germany), and chemical shifts are expressed as δ (ppm) with tetramethylsilane as internal standard.

All reagents used for experiments were analytical reagent grade. Extra pure methanol was purchased from Scharlau chemical company. Quercetin.$2H_2O$, and other reagents purchased from Sigma Chemical Co.

B. Synthesis

In a 100-cm^3 flask provided with electromagnetic stirrer were placed solid and yellow colored quercetin (0.151 g, 0.025 M) and extra pure methanol (20 ml). Until the solid quercetin has become completely dissolved it was stirred and then quickly (0.225 g, 0.05 M) of solid $SnCl_2.2H_2O$ salt was added into the flask ingredients, immediately the color changed to the yellowish brown which shows very quick interaction between quercetin and Sn(II), and the reaction mixture was kept at room temperature for about 6 hours. Then, the reaction mixture was filtered, and the filtrate was dried in vacuum evaporator and was used for spectroscopic and other studies.

III. RESULTS & DISCUSSION

A. UV-visible study of the complex

UV-visible spectra of the free quercetin and quercetin-Sn (II) complex are reported in (Fig.2)

When the solution of Sn(II) was added, band I gradually shifted to longer wavelengths, accompanied with slight decrease in absorption. Simultaneously, a new stronger absorbance peak appeared at 435 nm (Fig. 2). The results indicated formation of a complex between quercetin and Sn(II). There are two possible chelating sites on quercetin that can interact with Sn(II) : the 3- or -hydroxyls, and the 4-carbonyl. The appeared new peak at 454 nm suggested that Sn(II) had bonded to 3-hydroxyl and 4-carbonyl of ring C (9). Band I bathochromic shift can be explained by the interaction of Sn(II) with the 3-hydroxyl group of quercetin resulting in electronic redistribution between the quercetin molecule and Sn(II).

B. Infrared spectral study of the complex

IR spectroscopies of the quercetin and its complex were achieved by Bruker spectrophotometer in order to gain more information about the complex structure (Fig.3). Some information can be realized by comparing the absorption data of quercetin with the complex. The presence of peak at 424.81 cm^{-1} in IR spectrum of the complex (Fig.3b) indicates formation of (O–Sn) bond through the complex (10).The C=O stretching mode of the free ligand (Fig.3a) occurs at 1666.41 cm^{-1}. By the interaction of ligand with stannous chloride it has been shifted to 1642.90 cm^{-1} which can be explained by coordination of carbonyl oxygen with metal ion. The bands located in 1611.0 cm^{-1} and 1262.64 cm^{-1}, respectively are related to ν(C=C) and ν(C–O–C) vibration frequencies in ligand spectrum which are slightly shifted after complexation with tin. Moreover an increase in bond order (from 1319.09 cm^{-1} in the ligand to 1341.85 cm^{-1} in the complex) indicates involving of ν(C–OH) deformation mode, which is obvious when *ortho*-dihydroxy group in quercetin B ring coordinates in metal chelation. The big bound of ν(O–H) vibration frequency (from 3408.10 to 3384.82 cm^{-1}) indicates the existence of water in the complex.

C. ^{1}H NMR study of the complex

^{1}H NMR spectra of free quercetin and the complex were obtained by using DMSO as a solvent and the main data are reported here: Quercetin; δ12.49 (1H, 5-OH); δ10.8 (1H, 7-OH); δ9.6 (1H, 3-OH); δ9.39 (1H, 4′-OH); δ9.29 (1H, 3′-OH); δ7.67 (1H, H-2′); δ7.54 (1H, H-6′); δ6.89 (1H, H-5′); δ6.40 (1H, H-8); δ6.18 (1H, H-6) Quercetin-Tin(II) complex; δ10.71 (1H, 7-OH); δ9.58 (1H, 3-OH); 9.37 (1H, 4′-OH); δ7.9 (1H, H-2′); δ7.67 (1H, H-6′); δ6.89 (1H, H-5′); δ6.59 (1H, H-8); δ6.19 (1H, H-6). ^{1}H NMR data of the complex formed between quercetin and stannous chloride indicates that 5-OH and 3′-OH group protons are not present in the complex; however 3 other hydroxyl group (7-OH, 3-OH and 4′-OH) protons were remained after chelation. These data from ^{1}H-NMR fulfill the data of UV-visible and IR spectroscopic studies.

IV. CONCLUSION

Spectroscopic studies on the whole characterize that the proposed structure for the complex is like Fig .6 and quercetin molecule can chelate stannous cations from both 5-hydroxy-carbonyl and the 3′,4′-dihydroxyl (catechol) chelation sites. This structure explains the coordination of B-ring in cinnamoyl system and involving of benzoyl system (A-ring in Fig.1b) from the data acquired by UV, IR and also ^{1}H-NMR.

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REFERENCES

[1] Cody, V., Middleton, E. Jr., & Harborne, J. B. (1986). Plant Flavonoids in Biology and Medicine: Biochemical Pharmacological, and Structure-Activity Relationships. Alan R. Liss, Inc., New York. pp. 17.

[2] Fernandez, M. T., Mira, M. L., Florencio, M. H., & Jennings, K. R. (2002). Iron and copper chelation by flavonoids: an electrospray mass spectrometry study. Journal of Inorganic Biochemistry, 92, 105-111.

[3] Cornard, J. P., Boudet, A. C., & Merlin, J. C. (2001). Complexes of Al(III) with 3′4′-dihydroxy-flavone: characterization, theoretical and spectroscopic study. Spectrochimica Acta Part A, 57, 591-602.

[4] [4] Cornard, J. P., Dangleterre, L., & Lapouge, C. (2005). Computational and spectroscopic characterization of the molecular and electronic structure of the Pb(II)-quercetin complex. Journal of Physical chemistry. A., 109, 10044-10051.

[5] Eisler, R. (1989). Tin hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service. Biological report, 85, 1-15.

[6] WHO. (1980). Tin and organotin compounds: a preliminary review. Environ. Health Crit. 15. World Health Organization, Geneva, Switzerland. pp. 109.

[7] Tipton, I. H., Stewart, P. L., & Dickson, J. (1969). Patterns of elemental excretion in long term balance studies. Health Physics, 16, 455-462.

[8] Chen, W., Sun, S., Cao, W., Liang, Y., & Song, J. (2009). Antioxidant property of quercetin-Cr(III) complex: The role of Cr(III) ion. Journal of Molecular Structure, 918, 194-197.

[9] Kang, J.W., Zhuo, L., Lu, X.Q., Liu, H.D., Zhang, M., Wu, H.X. (2004). *Electrochemical investigation on interaction* between DNA with quercetin and Eu-Qu3 complex. J. Inorg. Biochem. 98, 79-86.

[10] Nakamoto, K. (1986). Infrared and Raman Spectra of Inorganic and Coordination Compounds. (4th ed.), Wiley, New York.

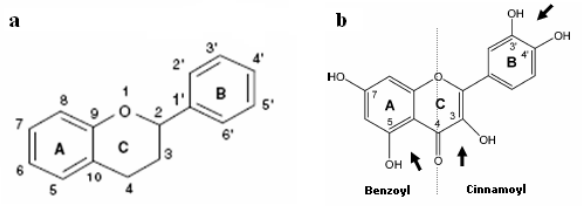

Figure1. (a) Basic structure of flavonoids and (b) Structure of the quercetin, a flavonol.

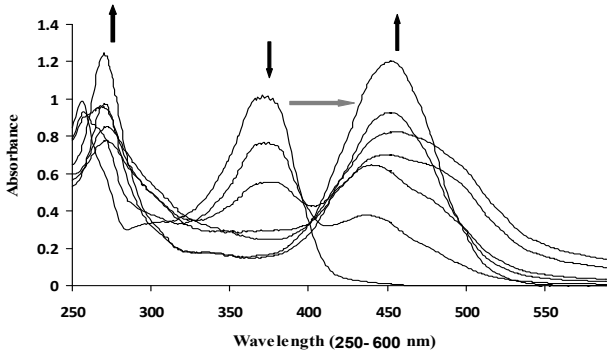

Figure 2. UV–Vis spectra of the ligand quercetin and the quercetin–Sn(III) complex in methanol

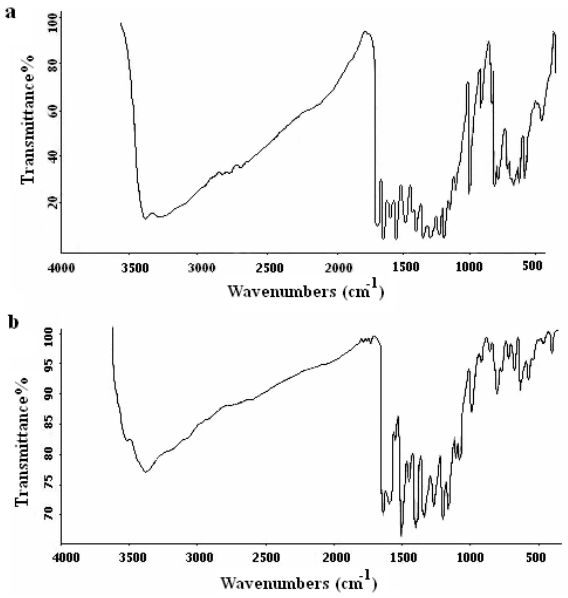

Figure 3. IR spectra of (a) quercetin, and (b) the complex of quercetin-Sn(II).