Coordination Chemistry Reviews 374 (2018) 497–524

Contents lists available at ScienceDirect

Coordination Chemistry Reviews

journal homepage: www.elsevier.com/locate/ccr

Review

Recent progress in synthesis and characterization of metal chalcone complexes and their potential as bioactive agents

Chiara Sulpizio, Joscha Breibeck, Annette Rompel *

Universität Wien, Fakultät für Chemie, Institut für Biophysikalische Chemie, Althanstraße 14, 1090 Wien, Austria

ARTICLE INFO

Article history:
Received 13 April 2017
Accepted 27 May 2018

Keywords:
Carbonyl compounds
Synthetic strategy
Structure activity relationship
Trends in bioinorganic chemistry
Biological application

ABSTRACT

This review presents an overview on the synthesis, characterization and applications of metal complexes containing chalcone (1,3-diphenylprop-2-en-1-one) and its derivatives as ligands, and the particular coordination chemistry of these versatile ligands is discussed. Synthetic strategies leading to stable and crystallizable metal chalcones complexes are outlined. The unique coordination chemistry of this class of organic compounds is assessed by structural comparison of representative chalcones in their free and metal-bound state, respectively. Finally, this outline is complemented by recent developments of biological applications of metal chalcone complexes, as a limited number of application studies indicates pharmaceutical potential in some areas such as anticancer activity and selective cytotoxicity, antioxidant and antibacterial effects. Overall, this review provides the first general overview of this emerging and rapidly expanding field of interdisciplinary research.

Contents

1. The characteristics of chalcone based ligands . . . 498
   1.1. The chemical structure of chalcones . . . 498
   1.2. History and uses of chalcones . . . 499
2. Metal chalcone complexes . . . 499
   2.1. Background . . . 499
   2.2. Coordination modes of chalcone and its derivatives . . . 499
   2.3. Synthesis of metal chalcone complexes . . . 501
   2.4. Characterization of metal chalcone complexes . . . 502
   2.5. Changes to the chalcone structure caused by metal coordination . . . 504
3. Reported metal chalcone complexes . . . 504
   3.1. Beryllium and magnesium chalcone compounds . . . 507
   3.2. Chalcone compounds with the early and middle transition metals Ti(*III*), V(*II*/*III*/*IV*), Cr(*II*/*III*), W(*0*) and Mn(*II*) . . . 507
      3.2.1. Stoichiometry and structure of titanium, vanadium, chromium, tungsten and manganese chalcone complexes . . . 507
      3.2.2. Biological activity of vanadium, chromium and manganese chalcone complexes . . . 507
   3.3. Iron chalcone compounds . . . 514
      3.3.1. Stoichiometry and characterization of iron(*0*/*III*) chalcone complexes . . . 514
      3.3.2. Antibacterial and cytotoxic activity of iron(*III*) chalcone complexes . . . 514
      3.3.3. Ferrocenyl chalcones . . . 515

Abbreviations: COND, conductivity; CT-DNA, calf thymus DNA; CV, cyclic voltammetry; DMF, dimethylformamide; DMSO, dimethylsulfoxide; DPPH, 1,1-diphenyl-2-picrylhydrazyl radical; EA, elemental analysis; EPR, electron paramagnetic resonance; IC_{50}, half maximal inhibitory concentration; IR, infrared spectroscopy; Job, Job's method of continued variation; MM, magnetic measurements; MS, mass spectrometry; NMR, nuclear magnetic resonance; nr, not reported; O, octahedral; Ph, phenyl group; PL, photoluminescence; PXRD, powder X-ray diffraction; Py, pyridine; SP, square pyramidal; SQ, square planar; T, tetrahedral; TA, thermal analysis; TC, theoretical calculation; UV–Vis, Ultraviolet–visible; XRD, X-ray diffraction.

* Corresponding author.
E-mail address: annette.rompel@univie.ac.at (A. Rompel).
URL: http://www.bpc.univie.ac.at (A. Rompel).

https://doi.org/10.1016/j.ccr.2018.05.023
0010-8545/

3.3.4. Nematocidal and cytotoxic activity of ferrocenyl chalcones . . . 516
3.4. Ruthenium(*II*/*III*) chalcone compounds . . . 516
3.4.1. Stoichiometry and characterization of ruthenium chalcone compounds . . . 516
3.4.2. Biological activities of ruthenium chalcone compounds . . . 516
3.5. Cobalt(*II*), nickel(*II*) and palladium(*II*) chalcone compounds . . . 517
3.5.1. Stoichiometry and characterization of cobalt, nickel and palladium chalcone compounds . . . 517
3.5.2. Biological activity of cobalt and nickel chalcone compounds . . . 517
3.6. Copper(*I*/*II*) chalcone compounds . . . 518
3.6.1. Stoichiometry of copper chalcone compounds . . . 518
3.6.2. Biological activity of copper chalcone compounds . . . 518
3.7. Zinc(*II*), cadmium(*II*) and mercury(*II*) chalcone compounds . . . 519
3.7.1. Stoichiometry, synthesis and characterization . . . 519
3.7.2. Biological activity . . . 520
3.8. Chalcone compounds with the post transition metals gallium(*III*) and tellurium(*IV*) . . . 520
3.8.1. Synthesis, stoichiometry and characterization of gallium and tellurium chalcone complexes . . . 520
3.8.2. Biological activity . . . 521
3.9. Lanthanide(*III*) chalcone compounds . . . 521
4. Future direction . . . 521
5. Conclusion . . . 522
Acknowledgments . . . 522
References . . . 522

1. The characteristics of chalcone based ligands

1.1. The chemical structure of chalcones

Chalcones (1,3-diarylprop-2-en-1-one) are natural products belonging to the flavonoid family, which are abundant in edible plants [1]. The chemical structure of a flavonoid can be visualized as two benzene rings (A- and B-rings) which are connected by a short three carbon chain (see Fig. 1). For all subclasses of flavonoids, except for chalconoids, the short chain is connected to one of the benzene rings, either directly or through an oxygen bridge, thereby forming a third five or six-membered ring (C-ring). The chalcone is reported as a natural precursor of an isoflavonoid; in fact, it is an unsaturated aromatic ketone consisting of 2 phenyl-rings, linked by an enone moiety, which forms the central core for a variety of important compounds. The cyclization of chalcones leads to the formation of the isoflavonoid and flavone structure (see Fig. 1) [1]. Chalcones can exist in two isomeric forms ((*Z*) and (*E*)), of which the (*E*)-isomer is considered thermodynamically favorable [2].

At first glance, a chalcone is just another substituted α,β-unsaturated carbonyl ligand related to the flavonoid compounds family. However, chalcones are effective metal ion chelators and they can easily create metal-coordinated compounds. All types of chalcones possess three main domains to interact with metals, which are the functional groups located on the A and B ring, as for example the 3,4-dihydroxy system located on the B ring in polyhydroxychalcones, the keto(-enol) moiety and the olefinic moiety (Fig. 1). Various changes of the substituents at the phenyl rings are possible, e.g. by converting the phenolic –OH group into –OR, –OC(O)R or –OC(O)OR (R = e.g. Me, Et) functionalities. Further functionalization can be achieved, for instance, by alkylation at the α,β-unsaturated carbonyl moiety in a Michael addition reaction [3,4].

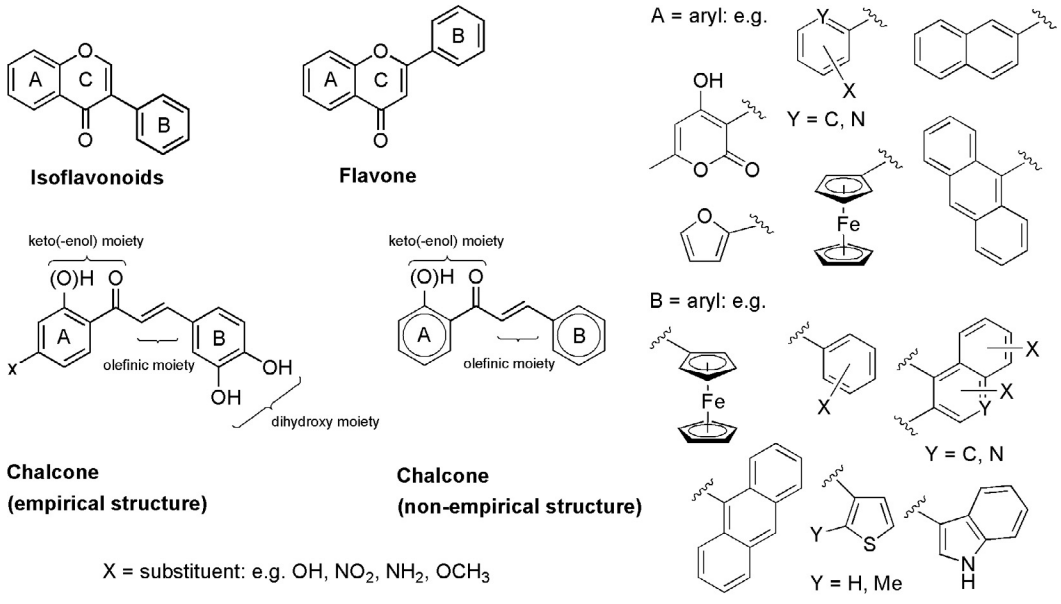

Fig. 1. Structure of different types of flavonoids and chalcone framework (1,3-diphenylprop-2-en-1-one) with commonly used substituents. Empirical chalcone structures can be expanded to non-empirical structures including aromatic polycyclics, heterocyclics and ferrocenes.