

THESES OF PH. D. DISSERTATION

**NEW PEPTIDE-TYPE TRIPODAL LIGANDS AND THEIR
METAL COMPLEXES: SYNTHESIS, THERMODYNAMIC AND
STRUCTURAL STUDY, APPLICATION IN CATALYTIC
FUNCTION**

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I. INTRODUCTION

In these days, one of the most important directions of modern bioinorganic research is the development of artificial enzymes. These small molecular compounds can mimic the catalytic functions of enzymes with high efficiency, allowing the substitution of these biomolecules in several industrial processes. On the other hand, enzyme-mimicking studies may help us uncover molecular mechanisms working in native biological systems.

Transition metal complexes are ideal candidates for structural and functional metalloenzyme modeling. One pathway of this strategy concerns the study of amino acid sequences present in the active centers of metalloenzymes; the investigation of metal-ligand interactions with model peptides of different length. These studies provide useful information on the significance of the amino acids present in the active center, and also on their role in the regulation of the enzymatic process, through *e.g.* metal binding, substrate binding, substrate activation or acid/base catalytic functions. Linear peptides, however, have their limitations in reconstituting the active centers of metalloenzymes, since they do not possess the well-defined three dimensional structure provided by the folded polypeptide chain. Therefore, the stability of their metal complexes is relatively low, with respect to that of the native active site, preventing the development of efficient catalytic activity.

One possibility for improving metal binding capabilities of linear peptides is their functionalization with tripodal ligands. Tripodal compounds may provide a rigid, less flexible platform for the coordinating amino acid side chains, creating a pre-organized metal binding site. The tripodal structure can stabilize special, distorted geometries often seen in the active sites of metalloenzymes. In addition, with targeted functionalization of the ligands, useful new functions, like substrate binding site or allosteric metal binding site, can be inserted to the molecule, which can help in the fine-tuning of catalytic activity. Considering all these, we can design tripodal peptide ligands, which might form highly stable metal complexes with convenient structure, fulfilling the basic prerequisite of efficient enzyme mimicking.

II. AIMS

The main objectives of the present work concern the synthesis, solution equilibrium and structural study of new peptide type tripodal ligands and their copper(II) and zinc(II) complexes, and the applications of these complexes as catalysts in redox and hydrolytic enzymatic model reactions. Since metal coordination occurs by histidine side chains in the majority of native metalloenzymes, our primary motivation was to study histidine-functionalized tripodal ligands. We intended to put proportional effort in the exploration of the coordination properties and the study of enzyme-mimetic behavior. Accordingly, the main goals of the work can be concluded as below:

- (1) To investigate the effect of the tripodal platforms, as well as the N- and C-terminal histidines on the thermodynamic stability of the studied metal complexes.
- (2) To determine the impact of asymmetric functionalization of tripodal arms on complex formation.
- (3) To identify the role(s) of the tripodal and the amino acid moieties in the structure of the formed complexes, with respect to geometry, coordination number and dominant binding modes.
- (4) To study the catalytic activity of our complexes in simple enzymatic model reactions, *e.g.* catechol oxidation or superoxide dismutation.
- (5) To find connections between the observed catalytic activities and the structural properties of metal complexes. One of our goals was to compare our systems with catalytically active, related linear peptide complexes, since these findings can be important steps in the future development of new, more efficient enzyme-mimetic compounds.

III. EXPERIMENTAL TECHNIQUES AND METHODS

Synthesis of the ligands

All discussed ligands were prepared and purified in the preparative laboratories of the Department of Inorganic and Analytical Chemistry, University of Szeged. Ligands nta1his and nta1his-NH₂ were synthesized using solid phase peptide synthesis method; all other ligands were prepared by solution phase peptide coupling. The schematic structures of the synthesized ligands are depicted in Figure 1.

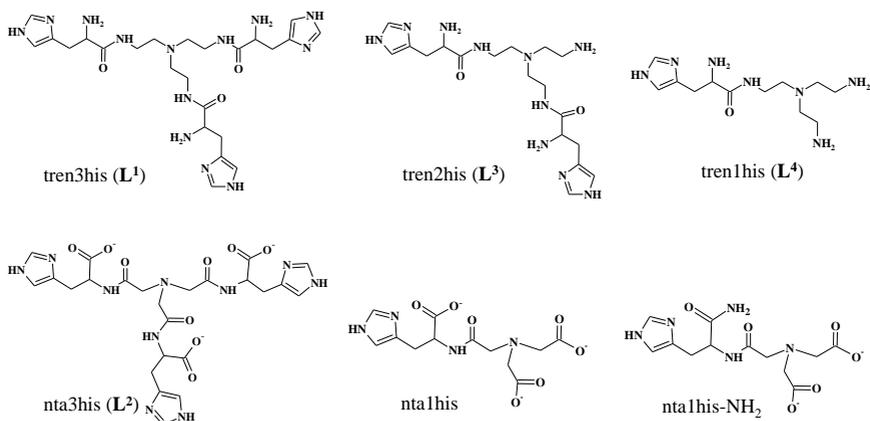


Figure 1. Designation and schematic structure of the discussed ligands.

Solution equilibrium study

In order to investigate the (de)protonation processes of the ligands and to determine the stabilities of the forming metal-ligand species, *pH potentiometric titrations* were carried out. The measurements were performed in aqueous media, at 0.1 M NaCl ionic strength and 25 °C, at different metal-to-ligand ratios. Titrations were evaluated using SUPERQUAD and PSEQUAD programs.

Spectroscopic methods

Several different spectroscopic techniques were used to describe solution structure of the metal-ligand complexes. For the identification of the coordinating groups and the main binding modes in copper(II) complexes, *UV-visible (UV-Vis)* and *circular dichroism (CD) spectroscopy* were used. pH-dependent spectra were processed together with potentiometric data in order to obtain individual molar UV-Vis and CD spectra for the main complex species. *Electron paramagnetic resonance (EPR) spectroscopy* was applied for the estimation of geometry and number of N-donor groups in the copper(II) complexes; in some cases, formation constants were also obtained from these measurements. The mentioned spectroscopic methods were all used, beside the investigation of the metal-ligand binary complexes, in substrate binding experiments as well.

The main tool for studying zinc(II) complex formation was the *nuclear magnetic resonance (NMR) spectroscopy*. pH-dependent ^1H NMR spectra were recorded to identify deprotonating and coordinating groups of the ligands. We applied two-dimensional NMR techniques (^1H - ^1H *COSY* - correlation spectroscopy, ^1H - ^1H *TOCSY* - total correlation spectroscopy, ^1H - ^1H *ROESY* - rotating-frame Overhauser spectroscopy) in order to prove some special structural features. Another special application, the *DOSY* (diffusion-ordered spectroscopy) method helped us to shed light on some interesting metal-induced oligomerization processes.

Mass spectrometric (MS) measurements were used to support the existence of the proposed complexes at various metal-ligand ratio. Whereas ligand molecules and mononuclear complexes were detectable by ESI (electrospray ionization) mass spectrometric method, the detection of multinuclear species required the application of MALDI-TOF (matrix-assisted laser desorption/ionization time-of-flight) MS technique.

Kinetic measurements

Catalytic activities of the metal complexes were investigated in *phosphoester hydrolysis*, *catechol oxidation* and *superoxide dismutation* reactions. The

experiments were carried out in buffered solutions, at 0.1 M ionic strength and 25 °C. The reactions were followed by spectrophotometry, determination of pseudo-first order reaction rate constants (k_{obs}) were accomplished according the initial reaction rates method. Autohydrolysis or -oxidation rate of the substrates were taken into account. Enzyme-kinetic parameters (k_{cat} and K_{M}), used for characterization of catechol oxidase activities, were calculated based on the Michaelis-Menten equation, with non-linear regression of the data.

IV. NEW SCIENTIFIC RESULTS

1. Solution equilibrium and structural study of the C_3 symmetrical, free N-terminal histidine containing ligand tren3his (L^1) and its metal complexes [1-3]

- 1.1. The formation of 1:1 and 3:2 metal-ligand complexes was observed in presence of both Cu^{2+} and Zn^{2+} ions; these complexes could be detected by MALDI-TOF MS method as well. In the acidic-neutral pH range, *bis*-histamine-type coordination $\{2\text{N}_{\text{im}}, 2\alpha\text{NH}_2\}$ is dominating in the equatorial plane of both metal ions. MHL^1 complexes bearing this coordination showed decreased $\text{p}K$ values as compared with the same value of the free ligand, indicating the axial coordination of the third ligand ‘arm’.
- 1.2. In the basic pH range, complexes of the two metals undergo different coordinational changes. In presence of copper(II) ions, the deprotonations of the *bis*-histamine-type CuL^1 complex results in the coordination of the amide and the tertiary nitrogen. The characteristic CD spectrum of the forming CuH_2L^1 complex shows resemblance to that of the complexes of peptides modeling the prion protein ‘octarepeat’ domain [1]. In the zinc(II)- L^1 system, the metal ion partially hydrolyses, leading to formation of mixed hydroxo species ($\text{ZnL}^1(\text{OH})$ and $\text{ZnL}^1(\text{OH})_2$) in the higher pH range.
- 1.3. At metal excess, the highly stable *bis*-histamine-type binding provided by the two ligand ‘arms’ triggers the dimerization of the mononuclear units, with

the assistance of a third bound metal ion. The coordination environment in these 3:2 metal-ligand complexes presents analogy to that of the mononuclear species. Interestingly, this process becomes important even in equimolar solution of Zn^{2+} and L^1 ; the complex $\text{Zn}_3\text{H}_4\text{L}^1_2$ appears as major species at pH 10, 1:1 Zn^{2+} -to-ligand ratio. ^1H NMR spectra recorded of this complex presents a set of imidazole signals with different chemical environment, corresponding to slow ligand exchanging species. Further diffusion studies revealed that the peak set can be attributed to the presence of $\text{Zn}_{3n}\text{H}_x\text{L}^1_{2n}$ type oligomer complexes with slightly different hydrodynamic radii [3].

2. Solution equilibrium and structural study of the C_3 symmetrical, free C-terminal histidine containing ligand nta3his (L^2) and its metal complexes [1-2]

2.1. The C-terminal histidine containing nta3his ligand presents very different coordination properties towards Cu^{2+} and Zn^{2+} ions. In the copper(II)- L^2 system mono- and dinuclear complexes could be detected. The spectroscopic data are consistent with a highly stable, Cu(II)-Gly-His-like, $\{\text{N}_{\text{tert}}, \text{N}, \text{N}_{\text{im}}, \text{O}\}$ type coordination, dominating over the equimolar solution until pH 10. Above that, this structure transforms into the five-coordinate CuH_2L^2 complex, having an intermediate geometry between trigonal bipyramid and square pyramid.

Since the Gly-His-type binding mode involves only one 'arms' of the ligand along with the tertiary nitrogen, the other two histidine moieties allow the binding of a second copper(II) ion at metal excess; the imidazole and carboxylic groups participate in this coordination in the acidic-neutral, while amide nitrogens in the basic pH range.

2.2. The presence of Zn^{2+} ions causes precipitation between pH 6 and 9, already at relatively low (~ 1 mM) ligand concentration. This pH is too low for the formation of $\text{Zn}(\text{OH})_2$ precipitate; moreover, pH-dependent ^1H NMR spectra showed significant intensity loss regarding the ligand signals, marking the zinc(II)-ligand species as the source of precipitation. This phenomenon could

be suppressed at ligand excess ($Zn^{2+}-L^2 = 1:3.5$), even though the presence of *bis*-ligand complexes was not indicated, neither by NMR nor potentiometric data. Based on simulated distribution curves at 1:1 metal-to-ligand ratio, the precipitation could be attributed to the formation of ZnL^2 species.

2.3. Zn^{2+} -dependent 1H NMR spectra recorded at pH 7.8 and 9.5 indicated different ligand exchange rates in the neutral and the basic pH range. Taking into account that the dipeptide Gly-His forms the $\{N_{im},N',NH_2\}$ type species in presence of Zn^{2+} ions as well, and considering the strong analogy found between the Cu(II)-Gly-His and Cu(II)- L^2 systems, the assumption of the amide-coordinated $ZnH_{1.1}L^2$ complex seems to be accurate. This would certainly explain the deceleration of the ligand exchange processes in the basic pH range. Accordingly, the precipitating ZnL^2 species should be coordinated by imidazole/ COO^- groups, which leads, probably due to oligo-/polymerization, to significant decrease in solubility.

3. Solution equilibrium study of the asymmetrically functionalized, C-terminally free and protected histidine containing ligands nta1his and nta1his-NH₂ and its metal complexes

3.1. Mainly potentiometric data could be obtained for the *mono*-histidyl-functionalized ligands, since both compounds turned out to be unstable in standard conditions; their slow degradation could not be prevented even with careful storage at low temperature. Solution equilibrium studies of the freshly made samples revealed three deprotonation processes for both ligands, related to the imidazole, tertiary nitrogen and carboxylic functions. The most acidic carboxylic groups protonate only below pH 2.

3.2. The ligands present very similar speciation with both Cu^{2+} and Zn^{2+} ions. The predominant coordination mode, similarly to the metal- L^2 systems, the highly stable Gly-His $\{N_{im},N',N_{tert}\}$ -type binding: the $CuH_{1.1}L$ complex dominates over 7 pH units. The analogous Zn(II) complex forms more than two pH units higher, according to the higher preference of Cu^{2+} towards amide N' coordination.

4. Solution equilibrium and structural study of the asymmetrically functionalized, free N-terminal histidine containing ligand tren2his (L³) and its metal complexes [3-4]

4.1. We observed mono- and dinuclear complex formation in presence of both Cu²⁺ and Zn²⁺ complexes. At 1:1 metal-to-ligand ratios, the *bis*-histamine-type coordination is predominant until neutral pH. In basic solutions, amide nitrogen and tertiary nitrogen coordinated copper(II) species, and mixed hydroxo zinc(II) complexes formed, similarly to the tren3his ligand systems [3,4].

4.2. At metal excess, dinuclear copper(II) complexes start to form at pH 4; the Cu₂H₁L³ species dominates over 4 pH units [4]. The formation of dinuclear species is related to the presence of two distinguished metal binding site in the molecule: aside of the *bis*-histamine type coordination site, the primary tren NH₂, the tertiary amino group and two amide nitrogens act as secondary binding site at the center of the ligand. The so-forming dizinc(II) complexes present slow ligand exchange rate on the NMR time scale; the spectra indicated interesting dimerization processes, where the imidazole ring might act as bridging ligand [3].

5. Solution equilibrium and structural study of the asymmetrically functionalized, free N-terminal histidine containing ligand tren1his (L⁴) and its metal complexes [3,4]

5.1. The ligand forms only mononuclear complexes with both metal ions. In presence of copper(II) ions, CuHL⁴ and CuH₁L⁴ complexes are the major species. The latter complex is five-coordinated, similarly to tren-metal complexes, but the peptide-type functionalization causes considerable distortion in geometry. In presence of Zn²⁺ ions, the analogous ZnH₁L⁴ complex predominates in the whole pH range; the related ¹H NMR spectra is surprisingly complicated, due to the slow ligand exchange and the magnetically inequivalent CH₂ protons. The coordination sphere of the

MH₁L⁴ complexes is completed by an axially coordinating histidine-nitrogen donor group [3,4].

6. Catechol oxidase mimicking of the studied ligand-copper(II) complexes [1,4,5]

- 6.1. We observed significant catalytic activities in the oxidation of 3,5-di-*tert*-butyl catechol (H₂DTBC) in case of copper(II)-L¹ 3:2, copper(II)-L² 2:1 and copper(II)-L³ 2:1 systems. Reaction rates were investigated in details in function of pH, substrate, complex and oxygen concentrations. Substrate-dependent measurements resulted saturation-like behavior in all ligand systems, allowing the Michaelis-Menten enzyme kinetic treatment. In all cases, first order dependence was detected in the reaction rates regarding oxygen and complex concentrations.
- 6.2. Detailed mechanistic studies on copper(II)-L¹ and -L² systems revealed different mechanistic pathways for the catalytic oxidation of H₂DTBC. In the copper(II)-L¹ 3:2 system, substrate binding studies indicated the coordination of only one substrate molecule, despite the trinuclear complexes. Inert H₂DTBC binding studies and EPR measurements proved that the oxidation proceeds via the formation of a radical (semiquinone-type) intermediate, similarly to other monocopper(II) model complexes reported in the literature. In contrast, the copper(II)-L² 2:1 system carries out the oxidation of H₂DTBC with co-operating copper(II) centers, similarly to the enzymatic reaction route.
- 6.3. The dinuclear, catalytically active complexes of L³ present exceptionally high H₂DTBC binding abilities ($K_M \sim 10^{-5}$ M order of magnitude), according to our substrate binding studies. In consequence, the overall catalytic efficiency (k_{cat}/K_M) of this system is notably high, exceeding the same value of the copper(II) containing model complex possessing the highest k_{cat} value reported so far.

6.4. Comparison has been made between catechol oxidase mimicking complexes of tripodal and linear peptides. As a general feature, coordinated amide nitrogens were suggested to facilitate substrate binding by the abstraction of protons from the -OH groups of the incoming substrate, serving as supporting acid-base catalytic sites in catecholase mimicking Cu(II)-peptide complexes [5]. Furthermore, the structure organizing effect of the tripodal scaffold was found to influence positively the substrate binding capabilities of the complexes, and therefore, overall catalytic efficiency. The tripodal structure also favors the formation of multinuclear species, further improving catalytic properties by allowing two electron oxidation pathways.

7. Superoxide dismutase mimicking of the studied ligand-copper(II) complexes [4]

7.1. Except for copper(II)-**L**⁴, all investigated copper(II)-ligand systems perform significantly as superoxide dismutase (SOD) mimics in the modified McCord-Fridovich indirect test reaction. They all exceed the SOD activity of the free copper(II) ion. Their IC₅₀ values are in the same range as those determined in histidine containing linear peptide-copper(II) systems; however, their activity is still almost two order of magnitudes lower than that of the native Cu,Zn-SOD.

V. LIST OF PUBLICATIONS

Hungarian Scientific Bibliography (MTMT) identifier: 10040545

Publications related to the scope of the dissertation: **ΣIF: 6.183**

- [1] **Á. Dancs**, N. May, K. Selmeczi, Zs. Darula, A. Szorcsik, F. Matyuska, T. Páli, T. Gajda: *Tuning the coordination properties of multi-histidine peptides by using a tripodal scaffold: solution chemical study and catechol oxidase mimicking*
New J. Chem., **2017**, *41*, 808-823. IF: 3.277
- [2] Gajda T., Szorcsik A., **Dancs Á.**, Matyuska F.: *Polidentát tripodális ligandumok biomimetikus fémkomplexei*
Magyar Kémiai Folyóirat, **2017**, *123* (2), 94-100. IF: -
- [3] **Á. Dancs**, K. Selmeczi, I. Bányai, Zs. Darula, T. Gajda: *Increasing the histidine 'density' in tripodal peptides by gradual N-functionalization of tris(2-aminoethyl)amine (tren) with L-histidyl units: The effect on zinc(II) complexes*
Inorg. Chim. Acta, **2017**, *in press* (DOI: 10.1016/j.ica.2017.06.049)
IF: 2.002
- [4] **Á. Dancs**, K. Selmeczi, N. May, T. Gajda: *On the copper(II) binding of asymmetrically functionalized tripodal peptides: solution equilibrium, structure, and enzyme mimicking*
New J. Chem., *submitted* (IF: 3.269)
- [5] **Á. Dancs**, K. Selmeczi, D. Árus, D. Szunyogh, T. Gajda: *Catechol oxidase and SOD mimicking by copper(II) complexes of multihistidine peptides*
Int. J. Pept. Res., *accepted manuscript* IF: 0.904

Other publications: **ΣIF: 11.032**

- [6] D. Árus, N. V. Nagy, **Á. Dancs**, A. Jancsó, R. Berkecz, T. Gajda: *A minimalist chemical model of matrix metalloproteinases — Can small peptides mimic the more rigid metal binding sites of proteins?*
J. Inorg. Biochem., **2013**, *126*, 61-69. IF: 3.197

- [7] D. Árus, Á. Dancs, N. V. Nagy, T. Gajda: *A comparative study on the possible zinc binding sites of the human ZnT3 zinc transporter protein*
Dalton Trans., **2013**, 42, 12031-12040. IF: 3.806
- [8] F. Matyuska, A. Szorcsik, N. V. May, Á. Dancs, É. Kováts, A. Bényei, T. Gajda: *Tailoring the local environment around metal ions: a solution chemical and structural study of some multidentate tripodal ligands*
Dalton Trans., **2017**, 46, 8626-8642. IF: 4.029

ΣΣIF: 17.215

Lectures and posters at international conferences:

- (1) D. Árus, Á. Dancs, T. Gajda, N. V. Nagy: *A comparative study on the possible metal-binding sites of the human ZnT3 zinc-transporter protein - metal-binding properties of peptides modelling human ZnT3*
4th European Conference on Chemistry for Life Sciences (ECCLS)
2011.08.31-09.03. Budapest, Hungary – poster presentation
- (2) T. Gajda, D. Árus, A. Kolozsi, Z. Paksi, Á. Dancs: *Enzyme mimicking by metallopeptides - minimalist artificial metalloenzymes*
4th European Conference on Chemistry for Life Sciences (ECCLS)
2011.08.31-09.03. Budapest, Hungary – oral presentation
- (3) D. Árus, Á. Dancs, T. Gajda, N. V. Nagy: *On the possible metal binding sites of human ZnT3 zinc transporter protein*
International Conference for Young Chemists (ICYC)
2012.04.08-10. Amman, Jordan – oral presentation
- (4) Á. Dancs, N. V. Nagy, Zs. Darula, I. Bányai, T. Gajda: *Synthesis and characterisation of the metal-binding properties of a tripodal peptide 'prototype'*
12th European Biological Inorganic Chemistry Conference (EuroBIC)
2014.08.24-28. Zürich, Switzerland – poster presentation
- (5) Á. Dancs, K. Selmeçzi, Zs. Darula, B. Henry, T. Gajda: *Structure and catecholase activity of trinuclear copper(II) species of a tripodal peptide 'prototype'*
DocSciLor 2015
2015.06.04. Nancy, France – poster presentation
- (6) T. Gajda, Á. Dancs, F. Matyuska, A. Szorcsik, P. Borsoss, V. Dokonpil, A. Traj: *Metal ion complexes of some tren- and tach-based tripodal ligands*
International Symposium On Metal Complexes (ISMEC)
2015.06.24-28. Wrocław, Poland – oral presentation

- (7) **Á. Dancs**, K. Selmeczi, N. V. May, Zs. Darula, T. Gajda: *Tuning the coordination properties of multi-histidine peptides by using a tripodal scaffold*
13th European Biological Inorganic Chemistry Conference (EuroBIC)
2016.08.28-09.01. Budapest, Magyarország – oral presentation
- (8) **Á. Dancs**, F. Matyuska, A. Szorcsik, **T. Gajda**: *Tuning the metal binding properties by derivatization of tripodal platforms*
13th European Biological Inorganic Chemistry Conference (EuroBIC)
2016.08.28-09.01. Budapest, Hungary – oral presentation
- (9) **Á. Dancs**, K. Selmeczi, T. Gajda: *Coordination chemistry of histidine containing tripodal peptides – A comparative study on Zn(II) complex formation*
Journées de Chimie de Coordination (JCC)
2017.01.26-27. Grenoble, France – poster presentation
- (10) **F. Matyuska**, A. Szorcsik, N. V. May, **Á. Dancs**, É. Kováts, A. Bényei, T. Gajda: *Transition metal complexes of mono- and trisubstituted tren-derivatives*
XXVI. International Conference on Coordination and Bioinorganic Chemistry (ICCBIC)
2017.06.04-09. Smolenice, Slovakia – oral presentation
- (11) **Á. Dancs**, K. Selmeczi, T. Gajda: *L'effet de la plateforme tripode sur la coordination de Cu(II) par ligands peptidiques*
FrenchBIC 2017
2017.06.06-07. Toulouse, France – oral presentation
- (12) **Á. Dancs**, K. Selmeczi, T. Gajda: *Redox enzyme mimicking by copper(II) complexes of tripodal peptide ligands*
14th International Conference on Applied Bioinorganic Chemistry (ISABC)
2017.06.07-10. Toulouse, France – poster presentation
- (13) **Á. Dancs**, K. Selmeczi, T. Gajda: *Redox enzyme mimicking by copper(II) complexes of tripodal peptide ligands*
DocSciLor 2017
2017.06.15. Nancy, France – poster presentation

Lectures and posters at national conferences:

- (14) **Dancs Á.**, Árus D., Gajda T.: *A humán ZnT3 egyik fémkötő szekvenciájának vizsgálata*
XXXIV. Kémiai Előadói Napok (KEN)
2011.11.02-04. Szeged – oral presentation

- (15) Gajda T., **Dancs Á.**, Árus D.: *A humán ZnT3 cink-tanszporter fehérje lehetséges fémkötő helyeinek összehasonlító vizsgálata*
46. Komplexkémiai kollokvium
2012.05.21-23. Mátrafüred – oral presentation
- (16) **Dancs Á.**, Árus D., Gajda T.: *A humán ZnT3 fehérje lehetséges fémkötő helyeinek azonosítása*
XXXV. Kémiai Előadói Napok (KEN)
2012.10.29-30. Szeged – oral presentation
- (17) **Dancs Á.**, Gajda T.: *Egy tripodális peptidszármazék előállítás és fémkötő sajátságainak vizsgálata*
47. Komplexkémiai kollokvium
2013.05.29-31. Mátraháza – oral presentation
- (18) **Dancs Á.**, Nagy N. V., Árus D., Gajda T.: *A tripodális peptidok egy „prototípusának” előállítása és fémkötő sajátságainak vizsgálata*
XXXVI. Kémiai Előadói Napok (KEN)
2013.10.28-30. Szeged – oral presentation
- (19) **Dancs Á.**, Borsoss P., May N. V., Gajda T.: *Hisztidint tartalmazó tripodális pszeudopeptidok fémkomplexei*
49. Komplexkémiai Kollokvium
2015.05.26-28. Siófok – oral presentation
- (20) **Dancs Á.**, Selmeczi K., Gajda T.: *Egy tripodális pszeudopeptid réz(II)komplexeinek egyensúlyi, szerkezet- és enzimutánzó vizsgálata*
Innováció a Természettudományban - Doktorandusz konferencia
2015.09.26. Szeged – oral presentation
- (21) **Dancs Á.**, K. Selmeczi, Gajda T.: *Két hisztidintartalmú tripodális peptid összehasonlítása: egyensúly, szerkezet, pirokatechin oxidáz aktivitás*
50. Komplexkémiai Kollokvium
2016.05.30-06.01. Balatonvilágos – oral presentation