CATECHIN-ZINC-COMPLEX: SYNTHESIS, CHARACTERIZATION AND BIOLOGICAL ACTIVITY ASSESSMENT

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Abstract
Flavonoids have been the subject of research due to their abundance and versatility, which have been attributed to therapeutic benefits. Flavonoids have the potential to form metal complexes, which have been the focus of research due to their potential bioactivity and pharmacological effects. They often form complexes with a metal to ligand (M:L) molar ratio of 1:2 or 1:1, which have strong stability constants. The effectiveness with which flavonoids attach to metal ions is strongly connected with the type and state of transition metal ions. In this paper we displayed some of the methods of synthesizing flavonoid-metal complex and the biological activity assessment. The antioxidant effects were evaluated against free radicals (iron chelation and hydroxyl radical tests) and the inhibition of lipoxygenase. On the other hand, the antidiabetic potential was investigated by using alpha-amylase and alpha-glucosidase assays. The infrared, UV spectrophotometry and the scanning electronic microscopy results indicated the formation of small acicular crystals with specific absorption bands confirming the obtaining of the catechin-zinc complex (Cat-Zn complex). The antioxidant assays indicated changes in the potential of the newly formed complex, with different intensity of action depending on the test, whereas the inhibition of alpha-amylase and alpha-glucosidase showed better activity for the complex as compared to catechin and zinc acetate. In conclusion, maintaining or improving the antioxidant or enzymatic inhibitory properties of catechin, after complexation with zinc ions, may represent a benefit for the use of such compounds in preclinical studies, but further testing is necessary to fully understand the in vivo potential.

Rezumat
Flavonoidele au fost intens cercetate datorită abundenței și versatilității lor, și au fost atribuite o serie de beneficii terapeutice. Flavonoidele au potențialul de a forma compuși cu ionii metalici, aceștia fiind scopul unor studii de evaluare a potențialului biologic și farmacologic. Ele formează adesea complexe într-un raport molar metal la ligand (M:L) de 1:2 sau 1:1, care au constante de stabilitate puternice. Eficacitatea care împreuna flavonoidele se atașează la ionii metalici este strâns legată de tipul și starea ionilor de metal tranziațional. În acest studiu, am inclus câteva metode din sinteză a complexului flavonoid-metal și evaluarea activității biologice. Efectele antioxiante au fost evaluat împotriva radicalilor liberi (test de chelare a fierului și radicali hidroxil) și inhibarea lipoxygenazei. Pe de altă parte, potențialul antidiabetic a fost investigat prin utilizarea testelor alfa-amilazei și alfa-glucosidazei. Rezultatele spectrotometriei în infraroșu, UV și microscopiei electronice de scanare au indicat formarea de mici cristale aciculare cu benzi de absorbție specifice confirmând obținerea complexului catechin-zinc (Cat-Zn complex). Testele antioxiante au indicat modificări ale potențialului complexului nou format, cu intensitate diferită de acțiune în funcție de test, în timp ce inhibarea alfa-amilazei și alfa-glucosidazei a arătat o activitate mai bună pentru complex în comparație cu catechină și acetatul de zinc. În concluzie, menținerea sau îmbunătățirea proprietăților antioxiante sau inhibitoare enzimatiche ale catechinei, după complexarea cu ionii de zinc, poate reprezenta un beneficiu în cazul utilizării acestor compuși în studii preclinice, dar sunt necesare teste suplimentare pentru a înțelege pe deplin potențialul în vivo.

Keywords: flavonoids, metal-ion-complex, catechin-zinc-complex, antioxidant, antidiabetic potential

Introduction
Since the beginning of time, people have understood and studied the benefits of consuming different products derived from plants, which allows them to take advantage of the nutritional and medicinal benefits [3, 4, 11, 43]. Furthermore, the research was focused on the phytochemical components that differ from one another in terms of their structure and distribution, and as a result, grouped them into a variety of categories, such as alkaloids, terpenoids, chromones, xanthones, phytides, carotenoids and flavonoids. Flavonoids are also an important and very studied category. Among these, flavonoids have been the subject of a significant amount of research over the years due to the abundance and
versatility of flavonoids as well as their distinctive properties, which have been attributed to a large spectrum of therapeutic benefits [9, 24, 35, 37, 39, 42, 44]. Even now, the researchers try to acquire innovative pharmacological properties and to fully understand the mechanisms of action, this aim is being carried out by the idea that a lot of phytochemicals are being continuously uncovered in terms of therapeutic and clinical implementation [8-11, 13, 18, 31].

Flavonoids are a group of compounds that are based on the structure of 2-phenylchromen-4-one (2-phenyl-1-benzopyran-4-one). The majority of flavonoids, if not all of them, are coloured substances (the word flavonoid comes from the Latin word flavus, which means yellow). Research on flavonoids did not make significant headway until the 1990s, when the number of publications increased by approximately sixfold, from 524 in 1990 to 3147 in 2017. This was the first decade in which flavonoid research saw significant progress. As a consequence of this, it is now well established that flavonoids possess a wide and diverse range of biological activities [10, 11, 13, 23, 28-30, 46]. Some examples of these activities include anti-inflammatory [21, 24], antibacterial and antifungal [1, 47], neuroprotective [25, 37, 42, 44], cardioprotective [13], antioxidant [15, 18, 26, 29] and anticancer [18, 20, 26, 27, 31] properties.

In recent years, the ability of flavonoids to form metal complexes generated intense attention in both scientific and industrial communities due to the potential of an enhanced bioactivity and different pharmacological [8, 15, 17, 31, 38, 41, 43]. Metal chelation is one of the many features of flavonoids, and it is one of the most important one since it has such a significant impact on the amplitude of the pharmacological actions that flavonoids may accomplish modulating the bioavailability of various minerals and ions [1, 5, 11, 12, 17, 20, 22, 30, 37, 39, 42, 45].

Catechins are natural polyphenolic compounds – flavanols, belonging to the flavonoid family [8, 10]. They are found in abundant concentrations in a variety of fruits, vegetables and plant-based beverages. The name catechin is derived from Cutch tree (Acacia catechu L.f.). High concentrations of catechin can be found in fresh tea leaves, rock–rose leaves, broad beans, red wine, black grapes, strawberries and apricots. Apples, blackberries, broad beans, cherries, black grapes, pears, raspberries and chocolate are rich in epicatechin. The main dietary source of catechins is green tea [2, 10, 12, 23-26, 35, 37].

Due to the presence of carbonyl and hydroxyl functional groups, available groups can be chelated by metal ions, especially using various salts of transition metals, which have a role as a biological constituent in the body [9, 17, 20, 25, 32, 37, 42, 43, 45]. These complexes are considered to be responsible for the manifestation of the antioxidant and antiradical action. Studies have shown that these metal complexes with flavonoids determine the obtaining of a wider palette of properties and potentiate those characteristic of the initial compounds [8, 17, 22, 31, 38, 42-44].

![Chemical structures of the most common catechines](https://pubchem.ncbi.nlm.nih.gov/)

Starting from the fact that multiple food supplements contain high levels of flavonoid derivatives or plant extracts rich in catechins along with minerals and vitamins, we wanted to investigate the possible changes that occur when such components are taken together. Thus, our aim was to obtain and characterize a catechin-zinc complex (Cat-Zn complex), and to assess its in vitro potential in various tests.

**Materials and Methods**

**Starting materials**

Catechin (Cat, 98%), zinc acetate (Zn$^2+$, 98%), sodium hydroxide (NaOH, 99%) were purchased from Sigma-Aldrich (Germany). Ethanol (EtOH, HPLC grade), Methanol (MeOH, ≥ 99.8%), dimethylsulfoxide (DMSO, ≥ 99.5%, p.a.), acetone (≥ 99.5%, p.a.), chloroform (dried, ≥ 99.8% CHCl$_3$, ≤ 50 ppm H$_2$O) were purchased from Carl Roth (Germany). All reagents were used as received without any further purification.

**Instrumentation**

Structural characterization of the newly formed complex was carried out by FTIR (Fourier-transform infrared spectroscopy). The FTIR spectra were registered on an FT-IR Bruker Vertex 70 Spectrophotometer in the reflexional mode, by ATR technique. Analysis was done at a scan rate of 40/s in the range 4000 cm$^{-1}$ - 380 cm$^{-1}$. The determination was performed with approx. 1 mg of sample.

The UV-vis spectra were recorded on a Shimadzu UV-1280 spectrophotometer using very diluted solution samples (approx. 10$^{-5}$ M) in methanol [2, 6, 17, 18, 32, 34, 41].

![Chemical structures of the most common catechines](https://pubchem.ncbi.nlm.nih.gov/)
The morphology of the complex evaluated as powder was observed using by Environmental Scanning Electron Microscope type Quanta 200- FEI (SEM) at a resolution 2, 5 and 20 μm and obtained crystals were photographed with the incorporated Cannon camera [1, 2, 30, 31, 45, 47].

Synthesis

The synthesis protocol was followed by previous mentions by the literature with some modifications [32, 40, 41, 45, 47]. Briefly, for the catechin-zinc complex the catechin and the zinc salt was taken using a 1:1 molar ratio. Catechin was dissolved in methanol under continuous stirring, then the zinc salt was gradually added over 30 minutes. The covered flask was maintained for 3 hours at 40°C (on a hot plate magnetic stirrer). The reaction was stopped and allowed to cool to room temperature. After removing the solvent by filtration, a precipitate of yellowish-white colour that was washed several times with acetone and dried in an oven (40°C). The obtained precipitate was dried to constant mass and used for further studies.

In vitro biological activity evaluation

The investigation of the potential of the newly obtained complex consisted in the in vitro antioxidant and antidiabetic activity assessment.

Antioxidant potential

The antioxidant activity was established by the following assays.

Iron (II) chelation test. Ferrozine can quantitatively form complexes with ferrous iron yielding a pink colour. However, in the presence of chelating agents, there is disruption of the formation of the complex which leads to a decrease in the colour intensity. The ferrous ion was monitored by measuring the formation of a pink ferrous ion-ferrozine complex at 562 nm [12, 15, 41, 42]. The used method was similar with the one described by Burlec et al., 2022 [13].

Hydroxyl radical test. The hydroxyl radical, formed in the reaction between the ferrous ion and hydrogen peroxide, will hydroxylate the salicylic acid with the formation of a pink-purple compound with maximum absorbance at 562 nm [27]. Briefly, over 0.225 mL of sample solution in dimethyl sulfoxide (DMSO) were added 0.750 mL of 1.5 mM iron (II) sulphate solution, 0.9 mL of 20 mM sodium salicylate solution and 0.525 mL of 6 mM hydrogen peroxide solution. The mixture was kept for 30 minutes at 37°C, and after cooling to room temperature, the absorbance of the sample (control) was read at 562 nm compared to the control sample (control) in which the ferrous sulphate solution was replaced by bi-distilled water. The positive control was processed under the same conditions as the samples, but DMSO was used instead of the sample solution.

Inhibition of lipoxigenase (15-LOX) activity. The activity of 15-LOX was determined following the formation of reaction products at 234 nm [14]. All reactions were performed at a final volume of 2 mL and stirred using a magnetic bar at room temperature. The reaction medium used contained 0.1 M HEPES buffer (pH 7.4). The reaction was carried out by adding the inhibitor (complex) in methanol to the cuvette with the substrate buffer, and finally the enzyme was added. All steps were similar to the already described method [23, 26].

Antidiabetic effect

The antidiabetic activity was established by the following assays.

Alpha-amylose assay. Alpha-amylose catalyses the hydrolysis of starch with the release of glucose which reacts with dinitro-salicylic acid and forms a yellow-orange coloured compound with maximum absorbance at 540 nm. In the presence of enzyme inhibitors, enzyme activity is blocked or reduced with a reduction in the absorbance of the solution at 540 nm [3]. 0.4 mL sample solution in DMSO was mixed with 0.08 mL 2 IU/mL enzyme solution, 0.2 mL 0.5% starch and 0.16 mL 20 mM phosphate buffer pH 6.7 and maintained the solution for 10 minutes at 37°C. After 10 minutes, 0.32 mL of dinitro-salicylic reagent solution was added, and the reaction mixture was maintained for 15 minutes at 100°C. The solution was cooled, and the absorbance of the sample was read against the sample control in which no enzyme was added. The positive control was obtained in a similar manner using DMSO [26].

Alpha-glucosidase assay. Alpha-glucosidase catalyses the hydrolysis of pNFG to p-nitrophenylphosphate, a yellow compound with maximum absorbance at 405 nm. In the presence of inhibitors, the enzyme activity decreases or is blocked with the reduction of absorbance of the solution at 405 nm [4]. The methodology was similar to the one described by Iancu et al., 2020 and consisted in the mixing of 0.1 mL sample (DMSO) with 0.25 mL enzyme solution 1 IU/mL and the solution was maintained for 5 minutes at 37°C. After 5 minutes, 0.25 mL of 3 mM pNPG solution was added and maintained for 10 minutes at 37°C. The reaction mixture was brought to room temperature, 1 mL of 0.2 M Na2CO3 solution was added, and the absorbance of the sample (control) was read at 405 nm against the blank of the sample (control). The positive control included DMSO instead of the sample [26]. For the samples in which an enzyme inhibition capacity of over 50% was obtained, the IC50 value expressed in μg sample/mL final solution was calculated. IC50 was calculated taking into account the first lower value and, respectively, the first higher value of 50%, obtaining, by linear interpolation, the concentration of the antioxidant agent solution that corresponds to an activity of 50%.

Statistical analysis

All determinations were performed in triplicate, the results being expressed as the mean of 3 determinations ± standard deviation. For correct correlations and statistical
significance, t-student analysis was performed (p < 0.001).

Results and Discussion

Synthesis and Complexation yield

In this study, the most important assessed parameters were the molar ratio of the reactants, the solvents used to reach the highest yield, adjustment of reaction temperature and the pH of the solution to encourage the formation of the precipitate, and to increase the reaction yield [6, 17, 30]. Also, stirring time and speed were adjusted to favour intimate contact between the reactants (catechin and zinc salt) and the reaction medium. In Table I are displayed the reaction yields obtained changing these parameters. Although we tried to modulate the reaction medium by adjusting the pH, the most interesting results were obtained for the system where the pH was adjusted at pH = 8.5 using a 1 N NaOH solution.

Scientific data indicates that the best parameters should be adjusted to the methodology, solvents, lab equipment and the complexation process is also dependent on the metal salts, organic and inorganic derivatives allowing the formation of certain compounds in higher amounts [6, 17, 30, 31, 34, 38, 39].

<table>
<thead>
<tr>
<th>Sample</th>
<th>Complexation yield, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
</tr>
<tr>
<td>Cat-Zn-complex</td>
<td>35.00</td>
</tr>
<tr>
<td>pH</td>
<td>5</td>
</tr>
<tr>
<td>1 N NaOH</td>
<td>-</td>
</tr>
<tr>
<td>Boric acid</td>
<td>-</td>
</tr>
<tr>
<td>Phosphate buffer</td>
<td>-</td>
</tr>
<tr>
<td>1 N HCl</td>
<td>10.11</td>
</tr>
</tbody>
</table>

FT-IR analysis

The infrared spectrum of free catechin showed the ν(C=O) band shifted from 1657 cm⁻¹ to 1598 cm⁻¹ upon binding with Zn (II) ion. This was due to the formation of the coordination bond between the carbonyl oxygen and the metal ions. A new ring was formed in the complex which accentuated the conjugative effect, thus the characteristic IR absorption band ν(C=C) moved from 1619 cm⁻¹ to 1509 cm⁻¹. The vibrations at 634 cm⁻¹ observed in the complex implied the presence of the O-Zn bond, which was not present in free catechin. The FT-IR spectra of free catechin and the newly formed complex is shown in Figure 2.

UV-VIS spectra

For the catechin-zinc complex formed, the UV-VIS absorption spectra were recorded when a shift of the absorption maximum of the complex compared to the absorption maximum of catechin can be observed, which confirms the formation of the complex (Figure 3). The results of the UV-VIS spectra provided significant information on the formation mode of catechin-zinc bonds. The Zn(II) ion induced a π → π* transition and formed a condensed ring with catechin through the 3-OH and 4-oxo groups. The 5-OH group was not involved due to the lower protonic acidity and steric hindrance in the complex.

Morphology

SEM images of zinc complex with catechin revealed a fibrous morphology with acicular structure and uneven fracture. We observed the formation of small aggregates of crystals of 1 μm in size that show adhesion at the level of some larger segments, which may indicate centres of aggregation of different amounts of the complex. Various aspects of the obtained images are included in Figure 4.
Our method was similar to other described previously in the scientific literature. Flavonoids often function as hydrogen donors, which is one of the factors that leads to the development of metal coordination complexes that have a high degree of stability. In most cases, reflux condensation or synthesis at room temperature is used to create metal ion complexes, however reflux condensation is also an option. In order to improve flavonoid metal coordination, the phenolic hydroxyl groups are often deprotonated prior to metal coordination [41, 47]. Numerous research have revealed that flavonoids most often form complexes with a metal to ligand (M:L) molar ratio of 1:2, which has strong stability constants [9, 12, 22, 30]. The hydroxyl groups in the flavonoid structure and the keto group make up the chelating sites in the flavonoids. The literature also suggests that the effectiveness with which flavonoids attach to metal ions is strongly connected with the type and state of transition metal ions [2, 5-8, 17, 18]. Such changes are noted for our complex in the FTIR and UV spectra. Therefore, all the obtained data from FTIR, UV spectrophotometry and SEM analysis indicated the formation of the Cat-Zn complex. Taking into account all the results, the best conditions to obtain such a complex were given by methanol as solvent in a pH of 8.5, using NaOH (1 N) solution for optimum reaction environment.

Biologic Potential Assessment

Flavonoids are a class of polyphenolic compounds that are naturally found in plants and are involved in a wide variety of biological and chemical processes. They have a C6-C3-C6 ring system, and they can either be esterified or glycosylated in their natural form. Such compounds of vegetal origin, exhibit anti-oxidant action by neutralizing free radicals or other pro-oxidant compounds in living systems. In particular, they can also present pro-oxidant effects through the ability to reduce the ferric ion to ferrous ion which, through the Fenton reaction, generates hydroxyl radicals with an important oxidizing effect [42, 43].

Iron chelation assay

Chelation of ferrous ions also represents an indirect anti-inflammatory mechanism considering the fact that inflammatory processes are accompanied by oxidative phenomena in which ferrous ions are involved [24]. Based on these observations, there is a risk that some plant compounds generate ferrous ions with a pro-oxidant effect, and thus it is important to evaluate the capacity of extracts or plant compounds to chelate ferrous ions. The obtained results showed that through chelation the inhibitory activity of catechin decreases, whereas the activity of Zn^{2+} increases (Figure 5).
The complexation of catechin with zinc ions causes an important reduction of its chelating capacity for ferrous ions; so, if we compare the IC₅₀ value (1653.79 for Cat-Zn-complex versus 290.88 for catechin), a decrease in the chelating capacity of more than 5 times is observed. The zinc ion prevents the formation of the coloured Fe²⁺-ferrozine complex, a phenomenon that can be explained by the fact that the zinc ion is also a bivalent cation.

Maintaining the chelating capacity of catechin even after complexation with zinc ions has antioxidant benefits through the catechin itself, but also through the zinc ions that enter the body can be used for the synthesis of superoxide dismutase, an enzyme with a role in the decomposition of the superoxide radical anion. Catechin also has the ability to cross the blood-brain barrier and thus can reduce neuroinflammatory phenomena [25, 27, 37].

**Hydroxyl radical scavenger test**

Hydroxyl radicals are extremely aggressive prooxidant compounds because they induce oxidation reactions in the chain and can affect cellular and subcellular biological structures. Hydroxyl radicals also modify functional groups in the structure of proteins by changing their spatial structure and affecting biological function or inducing pathological phenomena such as atherosclerosis, neurological disorders and cancer [33].

Similar to the lipoxygenase inhibition test and in this hydroxyl radical scavenger test, the Cat-Zn complex showed a much-reduced action compared to catechin (over 7-fold reduction), a phenomenon that could be determined by the partial blocking of the hydroxyl groups in the structure catechins (Figure 6). Hydroxyl groups, especially those of the phenolic type, are proton donors and can neutralize free radicals. On the other hand, the complexation has a better impact on the zinc ions scavenger activity, which increased significantly (p < 0.001).

Studies in which catechin and zinc were used showed also that the antioxidant effects of catechin are better maintained when synthesizing nanoparticles with zinc oxide, compared to the catechin-zinc ion complex [8].

**Antidiabetic potential of the Cat-Zn-complex**

The digestion of food starch involves the participation of pancreatic alpha-amylase and alpha-glucosidase which will transform the starch into glucose molecules that are absorbed in the intestine, pass into the blood and cause postprandial hyperglycaemia. Its value is dependent on the available starch for digestion, the activity of the enzymes involved in digestion and the absorption capacity of the intestinal systems. The increase in blood sugar, above the physiological levels, determines the accentuation of the phenomenon of oxidative stress and the uncontrolled glycosylation of proteins with the worsening of symptoms in diabetes and the risk of organic complications [28, 36].
**Inhibition of alpha-amylase**

The Cat-Zn-complex analysed in the present study has a better alpha-amylase inhibition capacity, compared to zinc or catechin (Figure 8).

Inhibiting or reducing the activity of alpha-amylase and alpha-glucosidase is one of the therapeutic options in diabetes because the intestinal digestion of carbohydrates is reduced with the reduction of available glucose for absorption. Through this mechanism, postprandial hyperglycaemia and, indirectly, its negative consequences are reduced. Classical inhibitors, such as acarbose, present the risk of adverse digestive reactions and thus, compounds of vegetable origin or metal ions with a moderate inhibitory effect, may present an advantage [46].

Zinc ions reduce or block the activity of the enzyme by changing its secondary structure, with an increase in the frequency of areas with a beta-folded or linear structure at the expense of those with an alpha-helix structure. Changing the secondary structure will affect the structure of the active centre of the enzyme and reduce the interaction with the substrate [32].

Flavonoids modify the activity of the enzyme by creating hydrophobic interactions and hydrogen bonds with the amino acids in the enzyme structure and thus modify its spatial structure, affecting the correct enzyme-substrate interaction [29]. Spectroscopy and in *silico* studies have shown that flavanols and catechin can also interact with starch, blocking its access to the active centre of the enzyme [29, 32, 40, 41, 49]. Matowane *et al.* showed a 2.6-fold increase in the alpha-amylase and alpha-glucosidase inhibition capacity of the caffeic acid-zinc acetate complex compared to caffeic acid and a two-fold increase in the antioxidant effect of the complex compared to caffeic acid. The same study highlighted the ability of the complex to increase the action of insulin on the cellular uptake of glucose through GLUT-4 transporters [38].

The inhibition capacity of alpha-amylase, determined in the present study (IC$_{50}$ = 147.33 ± 5.19, p < 0.01 – very significant), is close to that highlighted by Yilmazer-Musa in the study on salivary alpha-amylase, for which the IC$_{50}$ value was 160 μg/mL.

![Figure 8. Alpha-amylase inhibition potential for the Cat-Zn complex](image)

**Inhibition of alpha-glucosidase**

Similar to the alpha-amylase inhibition test, the Cat-Zn-complex also reduced alpha-glucosidase activity, but with a much higher efficiency (Figure 9). The complex is approximately four times more active compared to the zinc sulphate that was used in the preparation of the complex. Compared to catechin, the complex presented a slightly increased inhibitory efficiency (p < 0.001, extremely significant).

Catechin reduces the activity of alpha-glucosidase by making hydrogen bonds with the functional groups of the amino acids in the enzyme structure [16]. Numerous studies highlight the ability of catechin and other polyphenols of vegetable origin to inhibit or reduce the activity of alpha-amylase or alpha-glucosidase, with sometimes much greater efficiency compared to acarbose, which is used as a pharmaceutical substance to reduce the digestion of carbohydrates [26, 28, 29, 32, 40, 48, 49].

The effect of zinc inhibiting alpha-amylase or alpha-glucosidase is also maintained when using it in the form of nanoparticles, observing similar to those obtained in the present study, a more intense action on alpha-glucosidase, compared to alpha-amylase [40]. All in all, the structure of the newly formed complex is determined by the structure of flavonoid and metallic ion that is involved which may impact the complex's biological interactions, which may be unique from the flavonoids that it was generated from [18, 22, 30-32, 42]. For example, transition metal ion complexes of quercetin and genistein dramatically modify the chemical characteristics of their particular parent flavonoids [34, 43, 45, 47]. There are also many synthetic substances that are derived from flavonoids that try to simulate the biological effects of the natural ones, or to achieve even greater effects by modulating the pharmacological activity to target different tissues and sustain normal function of affected organs [30, 42, 45].

**Conclusions**

The complex obtained by using zinc acetate and catechin was obtained with a good yield by using
methanol as solvent, and NaOH as coregulator. All modern techniques indicated the formation of the complex. Moreover, the antioxidant capacity varies depending on the assay, and the potential of the obtained complex is different from the initial reagents (zinc, catechin). Considering the importance of zinc for maintaining insulin stability and the beneficial effects of the complex to reduce carbohydrate digestion, we can appreciate the fact that such complexes could be useful in the therapy of patients with diabetes, and their in vivo toxicological and pharmacokinetic evaluation is necessary. Further research is needed to establish the true potential of catechin-zinc complexes found often in food supplements.

Conflict of interest
The authors declare no conflict of interest.

References


