UDC 543.064:543.42:543.068.53:546.4
DOI: 10.15587/1729-4061.2018.127419

DETERMINING THE MICROELEMENT COMPOSITION OF POPPY SEEDS USING SOLID-PHASE SPECTROPHOTOMETRY METHOD

E. Kostenko
Doctor of Chemical Sciences, Professor*
E-mail: Kostenkoelizaveta@ukr.net
E. Butenko
PhD, Associate Professor*
M. Golubeva**
L. Arseneva
Doctor of Technical Sciences, Professor**
E-mail: ars-l@ukr.net
*Department of Food Chemistry***
Department of Food Expertise*
***National University of Food Technologies
Volodymyrska str., 68, Kyiv, Ukraine, 01601

Запропоновано схему твердофазного спектрофотометричного та фотометричного визначення мікроелементного складу насіння маку, що використовується як харчова добавка для створення хлібобулочних і кондитерських виробів. Встановлено, що у зразку міститься, мг/кг: Cu(II) – 5,0; Pb(II) – 0,3, Zn(II) – 50, P(V) – 1600, K – 550, Na – 20, Ca – 1500, Mg(II) – 450; Fe(III) – 10; Cd(II) та Hg(II) – відсутні. Використані методики аналізу характеризуються простотою експерименту, екологічною безпечністю, не потребують спеціального коштовного обладнання, висококваліфікованого персоналу та стаціонарної лабораторії

Ключові слова: спектрофотометричне визначення елементів, харчові добавки, насіння маку, гібридні методи аналізу

Предложена схема твердофазного спектрофотометрического и фотометрического определения микроэлементного состава семян мака, которые используются в качестве пищевой добавки для создания хлебобулочных и кондитерских изделий. Установлено, что в образце содержится, мг/кг: Cu(II) – 5,0; Pb(II) – 0,3, Zn(II) – 50, P(V) – 1600, K – 550, Na – 20, Ca – 1500, Mg(II) – 450; Fe(III) – 10; Cd(II) и Hg(II) – отсутствуют. Использованные методики анализа характеризуются простотой эксперимента, экологической безопасностью, не требуют специального дорогостоящего оборудования, высококвалифицированного персонала и стационарной лаборатории

Ключевые слова: спектрофотометрическое определение элементов, пищевые добавки, семена мака, гибридные методы анализа

1. Introduction

Poppy seeds are one of the most important and oldest oil-bearing crops in the world. Therefore, quality control of poppy seeds and food products whose formulation includes it as a food additive is very important [1].

Fig. 1. Poppy seeds

This task cannot be solved without using, in order to assess product quality, modern analytical methods of control. Most quality control laboratories widely use simple and reliable photometric and, if possible, atomic absorption methods. Therefore, it is an important task to develop and implement scientifically-substantiated combined spectrophotometric ecological control over the food products' content of normed substances at the level of 0.1 MAC and below [2–5].

Among others, a method of solid phase spectrophotometry (SPS) proved to be promising in the analysis of food objects. It employs, as sorbents, weakly-light-scattering ion-exchange resins with immobilized analytical reagents. The method makes it possible to combine the sorption concentration of metal ions and subsequent photometric determining in the solid phase [2–5]. It is possible to concentrate analytes at the site of sampling. This shortens the duration and labor-intensity of analysis.

2. Literature review and problem statement

Poppy seeds possess both healing and toxic properties. The latter relates to those varieties of poppy that contains opium. A potential danger of the opium poppy is believed to be so high that, for example, it has been banned in Russia since 2004 to individually cultivate any opium-containing poppy varieties of the genus Papaver.

On the other hand, it is known that poppy seeds improve digestion, help in the fight against diarrhea and dysentery. Poppy seeds soothe the nervous system and help fight insomnia. Poppy contributes to calm convulsive coughing in all bronchopulmonary diseases, and partly relieves pain.

The ideal sleeping medicine is obtained from ripe ground poppy seeds, mixed with a little amount of honey. Poppy seeds relieve fatigue and cheer up; they have anticarcinogenic and bactericidal effect. Poppy is a source of calcium, magnesium, and copper. This produces bone strengthening and increased hemoglobin in blood [1].

Because healing and toxic properties of poppy seeds are attributed to chemical composition, in particular micro elements, we considered it interesting to develop a scheme of analysis of poppy seeds applying a solid-phase spectrophotometry method.

The unique properties of ion-exchanging materials, modified with various organic reagents, led to their widespread use across many industries.

Papers [2–7] show that solid-phase reagents are often employed at present for inorganic analysis: to determine micro elements in natural water, geological, biological and food objects, industrial materials. Direct determining of microquantity of metal ions in the presence of high salt background is a very difficult task. Preliminary concentration using complex-forming ionites with immobilized reagents makes it possible to improve sensitivity and reliability when determining the elements.

High selectivity and effectiveness of such modified ionites and sorbents other classes, combined with good kinetic properties, makes it possible to apply sorption methods for concentrating and separating in automated systems for determining ions in solutions with different instrumental methods. Therefore, the application of modified ionites is considered to be promising when determining toxic metals in drinking, natural, and waste water. Information on the practical use of SPS to determine Al (III), Be (II), Bi (III), Cd (II), Co (II), Cr (VI), Cu (II), Fe (III), Fe (II), Ge (IV), Mo (VI), Nb (V), Os (II), Pb (II), Pd (II), Ru (II), Sn (IV), Ti (IV), Th (IV), U (VI), Zr (IV), NO_2^-, PO_4^{3-}, F^-, Br^-, humic acids, bilirubin, polyesters, crown-ether is provided in papers [2–10].

Thus, paper [2] reports results of the study into chemical-analytical properties of solid-phase reagents with immobilized sulfophthalene dyes. The authors give metrological characteristics of several procedures for analyzing food objects. Review [3] reports results of the study into chemical-analytical properties of solid-phase reagents with immobilized azo-dyes. The authors give metrological characteristics of certain food analysis techniques, as well as results of determining toxic metals in them.

Review [4] presents information about the prospects and benefits of using a solid-phase spectrophotometry method in the analysis of food materials.

Paper [5] gives information on the results of determining the microquantity of metal ions in food products, as well as procedures for analysis using immobilized dyes immobilized on the anion-exchanger AB-17×8.

Reviews [6, 7] report data about using SPS for determining micro elements and organic compounds in different objects in the environment. Thus, paper [6] provides data on water and biological objects analyses. Authors of [7] paid more attention to the procedure for measuring an analytical signal from samples of the environmental objects. It follows from work [4] that the solid-phase spectrophotometry method was not used in the analysis of food objects before 1990.

In [8–10], there are data on the use of modified silica in the analysis of certain food objects.

Paper [8] summarizes results of determining the ions of toxic metals in waters at biological and food facilities using bromobenzothiazo, immobilized on silica gel.

Article [9] addresses the test-determining of lead and zinc in water by employing xylenol orange, immobilized on silica. The authors described the procedure and results of analysis of different samples.

Authors of paper [10] created a solid-phase reagent based on molybdophosphoric heteropolyacid and reported results of sorption-spectroscopic determining of ascorbic acid in beverages.

Work [11] describes the study into sorption of heavy metals by polyacrylate anion exchangers.

Authors of [12] investigated the sorption of metal ions by yeast; in [13] – by grains of wheat.

Authors [14] studied sorption and complex-forming of heavy metals by the anionite from wheat residues.

Paper [15] describes optimization of the properties of anionite, based on cellulose, for the sorption of Cr(VI) from aqueous solutions.

The concentration of tartrazine from aqueous solutions using strong-base polystyrene resins is addressed in [16].

Paper [17] describes the results of study into adsorption equilibria of a dye of the acid type and a gel anion exchanger.

One can see that there is no information in the scientific literature on the application of metallochromic indicators, immobilized on polymeric sorbents, for food analysis using a solid-phase spectrophotometry method.

Given the high metrological characteristics of SPS-procedures for conducting microelement analysis of food products, as well as their simplicity, affordability, and environmental safety [2–10], the expediency of undertaking our research is obvious.

Complex-forming of the ions of Pb^{2+}, Cd^{2+}, Hg^{2+}, Cu^{2+}, Zn^{2+}, Fe^{3+} with different dyes in the phase of a polymeric sorbent was previously investigated.

For example, paper [2] reports results of the study into interaction between Cd (II) and methylthymol blue in the phase of polymeric ion-exchanger. The authors established optimal reaction conditions and the composition of a complex, which is formed in the solid phase. The authors developed a procedure for solid-phase spectrophotometric determining of Cd (II) with a limit of detection of 0.22 µg/ml. It was [2] shown that the complex-forming of Hg (II) with chromazurol S in the phase of the polymeric anionite AB-17x8 is characterized by a conditional stability constant $\lg\beta_1=8.1\pm0.7$. The results obtained were used to develop a methodology for determining the microquantity of Hg (II) in mushrooms. The detection limit is 20 µg/l.

Paper [2] reports results of the study into the system Zn-MTB- AB-17×8). It is shown that the Beer’s Law holds in a concentration range of Zn (II) $(0.1–9.0)\times10^{-5}$ M; detection limit under optimal conditions is 0.065 µg/ml (V=50 ml). λ_{opt}=500 nm Determining Zn (II) by solid-phase MTB, SPh-MTB is prevented by ions in the following ratios: 1:50 – Fe (III); 1:100 – Ca (II), Mg (II), oxalates, tartrates; 1:500 – Cu (II), Pb (II), Hg (II), Cd (II), Co (II), Al (III), Sn (IV), Zr (IV), Ti (IV), fluorides, sulfates, thiosulfates, acetates; 1:1,000-nitrates, bromides, chlorides, thiocyanates.

The study of the complex-forming of Cu (II) by SPADNS in solution and in the solid phase made it possible to develop selective techniques for photometric and SPS-determining of the microquantity of copper [3].

Data on the studies into complex-forming of metal ions with PCV, XO, MTB, CAZ, as well as results of the development of new techniques for determining metals in the solid phase, are provided in [2–5]. Some results are given in Tables 1, 2.

Table 1

Characteristics of new techniques for the solid-phase-spectrophotometric determining of metal ions (V=50 ml, DL for $D_{\max}$)

Analyte	Solid-phase reagent	$\lambda_{\max}$, nm	DL, μmg/l
Cu(II)	$\overline{\text{SPADNS}}$	640	0.64
Pb(II)	$\overline{\text{XO}}$	560	20
Sn(IV)	$\overline{\text{XO}}$	540	20
Pb(II)	$\overline{\text{PCV}}$	640	20
Zn(II)	$\overline{\text{MTB}}$	500	10
Cd(II)	$\overline{\text{MTB}}$	640	30
Hg(II)	$\overline{\text{CAZ}}$	580	20

DL (detection limit) is calculated from formula $X_Q=(k\cdot\sigma_0:A):[1-(k\sigma_A:A)^2]^{1|2}$, where k is the tabular value of the Student's t-criterion; A is the sensitivity, coefficient at X in equation $Y=B+A\cdot x$, σ_A is the standard deviation of coefficient A, σ_0 is the standard deviation of X. $C_{\min}$ is calculated in accordance with the recommendations of IUPAC [18].

It was shown in [2–5] that the best, in terms of group concentration of the examined metal ions in acidic medium, are the ion exchangers with immobilized XO and CAZ.

$\overline{\text{XO}}$ makes it possible to concentrate ions of Cu (II), Pb (II), Hg (II), Fe (III) at pH 0.5–1. $\overline{\text{CAZ}}$ makes it possible to concentrate ions of Pb(II), Hg(II), Zn(II), Cd(II) at pH 2–2.5. It is also shown that using $\overline{\text{CAZ}}$ can separate, at pH 0.5–2, all the examined metal ions. In this case, the ions of Cu(II) and Fe(III) will remain in solution. One can then selectively determine the ions of Fe(III) at pH 3. Alternatively, one can determine Cu(II) after masking the ions of Fe(III).

$\overline{\text{SPADNS}}$ can also be applied to extract the ions of Cu(II).

The latter proved to be the best solid-phase reagent to extract the ions of Cu(II) at pH 3–6 from liquid food objects. SPADNS allows determining, both in solution and in the ion-exchange phase, Cu(II) with high sensitivity ($C_{\min}$=0.0064 μg/ml). Determining is not precluded by the ions of Pb(II), Hg(II), Zn(II), Cd(II), Fe(III), Sn(IV), since they form unstable complexes with $\overline{\text{SPADNS}}$.

$\overline{\text{PCV}}$ can be recommended for the selective extraction of Pb(II) ions at pH 0.5.

$\overline{\text{CAZ}}$ can be recommended for the phased concentration and separation of metal ions in small groups. In this case, it is possible, first, at pH 0.5–1, to separate the ions of Hg(II), Sn(IV), then, at pH 2–2.5, to separate the ions of Pb(II), Cd(II). Only the ions of Cu(II) and Fe(III) will remain in solution.

An analysis of data from the scientific literature shows that it contains no information related to SPS determining of micro-elemental composition of poppy seeds using SPADNS, $\overline{\text{SPADNS}}$, $\overline{\text{CAZ}}$, $\overline{\text{PCV}}$, $\overline{\text{XO}}$, $\overline{\text{MTB}}$, $\overline{\text{ARS}}$, $\overline{\text{ACS}}$, $\overline{\text{ECC}}$. Therefore, our research is justified.

3. The aim and objectives of the study

The aim of present study is to develop a scheme for the microelement analysis of poppy seeds. This would make it possible to monitor the quality of poppy by simple and affordable methods at industrial laboratories.

To accomplish the aim, the following tasks have been set:

– to define the prospects for the application of solid-phase reagents $\overline{\text{PCV}}$, $\overline{\text{XO}}$, $\overline{\text{MTB}}$ and SPADNS for an analysis of poppy seeds;

– to develop a scheme for analysis of samples of poppy seeds using azo- and sulfophthalene dyes, immobilized on the anionite AB-17×8.

Table 2

Chemical-analytical characteristics of certain solid-phase reagents (SR) to analyze the objects of food technology and objects of the environment

Analyte	SR/object of analysis	pH_{opt}	$C_{\min}$ (A), μmg/l	$C_{\min}$ (B), μmg/l	MAC, μmg/kg (μmg/l)	Determining is not prevented by ions
Cu(II)	$\overline{\text{SPADNS}}$/ drinking water	5.0–6.8	0.64	100 (Ph) 100 (P)	500	Pb(II) – forms unstable complex; Hg(II),Fe(III), Sn(IV), Zn(II), Cd(II) – do not form complexes; 1:200 – Zr(IV); 1:1,000 – aem, Cl^-, SCN^-, F^-, NO_3^-, Ac^-, SO_4^{2-}, CO_3^{2-}, $C_2O_4^{2-}$
Pb(II)	$\overline{\text{XO}}$/milk	3.0	20	50 (P)	50	1:10 – Sn(IV); 1:500 – Fe(III), Zr(IV); >1,000 – Zn(II), Hg(II), Cu(II), Cd(II), aem Cl^-, Ac^-, Asc^-, SCN^-, thiourea, NO_3^-, CO_3^{2-}
Pb(II)	$\overline{\text{PCV}}$ /milk	3.0	20	50 (P)	50	1:1,000 – Hg(II), Zn(II), Fe(III), Zr(IV), Cu(II), Sn(IV), Cd(II), Ti(IV), aem F^-, Ac^-, Cl^-, SCN^-, thiourea CO_3^{2-}, NO_3^-
Zn(II)	$\overline{\text{PCV}}$ /mayonnaise	3.0	10	200 (P)	3.0×10^3	1:1 – Hg(II); 1:50 – Fe(III), Zr(IV); 1:100 – Pb(II), Cu(II); 1:500 – Cd(II), Sn(IV), Ti(IV); 1:1000 – aem F^-, Cl^-, Ac^-, NO_3^-, SO_4^{2-}, CO_3^{2-}, $S_2O_3^{2-}$, $C_2O_4^{2-}$
Hg(II)	$\overline{\text{CAZ}}$ /mayonnaise	1.0	20	800 (VT) 0.1 (AAC)	20	1:10 – Sn(IV); 1:1,000 – Cd(II), Cu(II), Zn(II), Pb(II), Fe(III), Zr(IV), Ti(IV), aem Ac^-, F^-. SO_4^{2-}, NO_3^-, CO_3^{2-}

Notes: Procedures: (A) – new, (B) – standard, (Ph) – photometric, (P) – polarographic, (AAS) – atomic-absorption, (VT) – visual-testing

4. Materials and methods used in the development of a scheme for microelement analysis of poppy seeds

Reagents. The source 0.1 mol/l solutions of Cu(II), Pb(II), Zn(II), Fe (III), Hg(II), Cd(II) salts were prepared by dissolving the batches: $CuSO_4$×5 H_2O (pure), Zn^0 and Cd^0 (e.c.) in 0.1 and 1.0 mol/l H_2SO_4; $Pb(NO_3)_2$, $Fe(NO_3)_3$×6 H_2O, $Hg(NO_3)_2$×0,5 H_2O (pure) in 0.1 mol/l HNO_3 [2, 3].

The standardization was carried out: iodometrically (Cu), complexometrically (Pb), (Zn), gravimetrically (Fe), permanganatometrically (Fe), mercurimetrically (Hg) [2, 3, 5].

Standard aqueous solution of phosphorus with a titer of 10 μg/ml was prepared for the precise batch of KH_2PO_4 (chemically pure) 0.24 M, aqueous solution of $Na_2MoO_4{\cdot}2H_2O$ was for the precise batch.

We used metallochromic indicators: xylenol orange (XO), pyrocatechol violet (PCV), chromazurol S (CAZ), SPADNS p.f.a. (Chemapol), malachite green (MLG) p.f.a. (Merck), arsenazo III (ARS) chemically pure: acid chromium dark blue (ACDB), p.f.a.

Standard aqueous solution of phosphorus with a titer of 10 μg/ml was prepared for the precise batch of KH_2PO_4, chemically pure, 0.24 M; aqueous solution of $Na_2MoO_4{\cdot}2H_2O$ was prepared for the precise batch.

We used HC1, HNO_3, NaOH, NaC1, acetone, ethanol e.c.; 35 % hydrogen peroxide solution, chemically pure.

The starting 1.0 mol/l solutions of potassium thiocyanate and sodium fluoride were prepared by dissolving precise batches of respective preparations, chemically pure, in water. The starting 1.0 mol/l solutions of nitric acid and hydrochloric acid, 0.2 mol/l sulphuric acid solution, were prepared by diluting the concentrated solutions.

Working solutions were prepared by diluting the starting solutions prior to conducting the experiment.

We used anion exchanger AB-17×8 (A) in the Cl-form, grain size 0.25–0.50 mm, which was prepared in line with the procedure described in [2, 3]: 10 g A were wetted in a saturated solution of NaCl and left for 24 hours. Next, we separated the sorbent, washed it with 0.5 M solution of HCl until reaching a negative reaction on Fe^{3+} and washed it with water until reaching a neutral reaction. Polymeric matrix was modified with an aqueous solution of metallochromic indicator, as described in [2, 3, 5]. For this purpose, ~0.1 g of the indicator in 150 ml of water was treated with 10 g of air-dry A–Cl. The solid phase was filtered, washed with water, and drained. The obtained solid-phase reagents ($\overline{\text{SPADNS}}$, $\overline{\text{XO}}$, $\overline{\text{PCV}}$, $\overline{\text{MTB}}$, $\overline{\text{CAZ}}$, $\overline{\text{ARS}}$, $\overline{\text{ACS}}$, $\overline{\text{ECC}}$) are the transparent colored granules that reflect light well.

Preparation of the solid sample for the photometry implied obtaining a light-absorbing layer of the concentrate, evenly distributed in a cuvette. We used quartz cuvettes with parallel walls for measurements. The concentrate was transported using a pipette to a cuvette, which was filled with water in advance; another cuvette was filled similarly with AB-17×8-Cl or AB-17×8, the same grain size. Light-absorbing capacity of the examined samples was measured upon reaching maximally possible packing density of granules in the cuvettes. The solutions were agitated at a magnetic mixer.

5. Results of determining microelements in poppy seeds.

Results of the analysis of poppy seeds are given in Table 3.

Table 3

Results of the analysis of poppy seeds using new (A) and standard (B) procedures
(n=3, P=0.95, m_{poppy}=5 g (A), 50 g (B))

Analyte	Reagent	Methods (A)/(B)	MAC, μm/kg [17]	Introduced X, μm/kg of product	Detected X, μm/kg of product (A)	S_r	Detected X, μm/kg of product (B)	S_r
Cu (II)	SPADNS	(A) Ph	10.0	–	5.0±0.7	0.02	5.2±0.5	0.05
		(B) Ph		5	10.0±0.04	0.04	10.0±0.1	0.03
Pb (II)	$\overline{\text{PCV}}$	(A) SPS	0.5	–	0.30±0.02	0.02	0.30±0.05	0.02
		(B) P		0.5	0.80±0.02	0.04	0.80±0.01	0.04
Zn (II)	$\overline{\text{MTB}}$	(A) SPS	50.0	–	50±4	0.02	50±5	0.03
		(B) P		50	100±5	0.04	100±6	0.05
Cd (II)	$\overline{\text{MTB}}$	(A) SPS	0.1	–	<0.1	–	<0.1	–
		(B) P		0.5	0.50±0.01	0.04	0.50±0.02	0.02
Hg (II)	$\overline{\text{CAZ}}$	(A) SPh	0.03	–	–	–	0.004±0.001	–
		(B) AAC		1	1.0±0.1	0.04		0.03
P (V)	MLG	pH	Not standardized	–	–	–	1600±50	0.02
K (I)	–	FPh	Not standardized	–	–	–	550±10	0.03
Na (I)	–	FPh	Not standardized	–	–	–	20±2	0.04
Ca (II)	–	FPh	Not standardized	–	–	–	1500±70	0.03

6. Discussion of results on determining the microelements in poppy seeds

Table 3 gives the results of analysis of poppy seeds, conducted according to the following scheme:

1. Drying the samples in a drying chamber at t=100 °C and ashing in a muffle furnace at t=460 °C.
2. Preparation of nitric acid solutions of ash from poppy seeds to determine microelements in separate portions.
3. Preparation of reagents solutions and synthesis of the solid-phase dyes: $\overline{\text{PCV}}$, $\overline{\text{XO}}$, $\overline{\text{MTB}}$.
4. Photometric determining of P(V) in the form of an ion associate of molybdophosphoric heteropolyacid with malachite green.
5. Photometric determining of Fe(III) with ammonium thiocyanate.
6. Determining of Cu(II): binding of the ions of Fe(III) into a colorless fluoride complex, photometric determining using SPADNS at pH 6.0.
7. Determining Pb(II): binding of the ions of Fe(III) into a colorless fluoride complex, SPS determining using $\overline{\text{PCV}}$ at pH 2.
8. Determining Zn(II): removal of interfering cations to phase $\overline{\text{XO}}$ at pH 2–2.5 and separation of the solid phase. Formation of pH 3 in a liquid phase, SPS determining Zn(II) by $\overline{\text{MTB}}$.
9. Determining Cd(II): removal of interfering cations to phase $\overline{\text{KO}}$ at pH 2–2.5 and separation of the solid phase. Formation of pH 3 in a liquid phase, separation of Zn(II) by $\overline{\text{MTB}}$. Formation of pH 7 in a liquid phase and SPS determining Cd(II) by $\overline{\text{MTB}}$.
10. Determining Hg(II): binding of the ions of Fe(III) into a colorless fluoride complex, SPS determining using $\overline{\text{CAZ}}$ at pH 2.
11. Determining K(I), Na(I), Ca(II) by a flame photometry.

We used SPADNS to determine Cu(II) as the most selective reagent.

For the case of determining Pb(II), the best result was obtained when using $\overline{\text{PCV}}$. The latter enables the selective and sensitive determining of Pb(II) in acidic environment, in contrast to the immobilized arsenazo III.

$\overline{\text{KO}}$ proved to be the best reagent for the group concentration of interfering ions.

$\overline{\text{MTB}}$ and $\overline{\text{CAZ}}$ have proven to be effective reagents for the analysis of Cd(II) and Hg(II) in different food objects [2, 3] and for the case of poppy seeds.

Table 3 shows that poppy seeds contain a large number of ions of K, Ca, and P(V). This characterizes poppy as a valuable dietary supplement, promising for the creation of new food products.

The content of K, Na, Ca, and P(V) is not standardized.

It was established that the content of ions of Cu(II), Zn(II), Pb(II), Hg(II) does not exceed the maximum allowable concentration. This indicates the safety of poppy seeds as a food object.

The procedures used in this work are characterized by sensitivity and selectivity. High distribution coefficients ($D \geq 10^4$ cm^3/g) of metal ions reduce the detection limit when using an immobilized dye compared to the reaction in solution. In terms of DL, the employed procedures for the sorption-spectrophotometric determining of metal ions are inferior only to the methods of atomic-absorption (AAS) determining of ions of Cd(II) and Hg(II), and polar-graphical determining of ions of Cd(II). DL in the proposed procedures for determining these metal ions is sufficient to determine the Cd(II) and Hg(II) ions in food products at the level of MAC. The procedures for SPS determining of the ions of Pb(II), Zn(II), Cu(II) have advantages compared to standard procedures for determining metal ions in food products. Enhanced selectivity of determining using dyes, immobilized in ion exchangers is explained by a change in the microenvironment of dyes in the solid phase [2, 3].

Ion exchangers with immobilized dyes and solid-phase spectrophotometric determining procedures are environmentally safe, and do not require the application of toxic organic reagents. The procedures employed are easy to use, cost effective due to the low cost of the utilized materials and reagents [2–5].

Convergence of the analyses results, obtained using the new procedures for solid-phase spectrophotometric and photometric determining, with the results obtained using standard methods, testifies to the reliability of data reported. The relative standard deviation in the results does not exceed 0.10. This indicates satisfactory reproducibility of results.

The proposed scheme for analysis of poppy seeds is universal. It is possible to apply a given protocol for a microelement analysis of other food products.

This work is continuation of research topic "Polymeric ionites with immobilized dyes in hybrid spectrophotometric analytical methods", which will be further investigated. Procedures and analysis schemes could be improved.

6. Conclusions

1. We have substantiated the possibilities of applying the solid phase reagents $\overline{\text{PCV}}$, $\overline{\text{XO}}$, $\overline{\text{MTB}}$ and SPADNS for the analysis of poppy seeds.
2. We have developed a scheme of analysis of poppy seeds samples using azo- and sulfophthalene dyes, immobilized on the anionite AV-17×8. It was established that when determining cadmium and zinc, the best ion exchanger for the group concentration of interfering metal ions is the ion $\overline{\text{CAZ}}$, exchanger with the immobilized KO. $\overline{\text{CAZ}}$ makes it possible to concentrate and determine in the solid phase the ions of Hg(II). It is also shown that using $\overline{\text{PCV}}$ can selectively detect Pb(II). One can then selectively determine the ions of Fe(III) ions at pH 3, determine Cu(II) after masking the ions of Fe(III). $\overline{\text{SPADNS}}$ can also be applied to extract ions of Cu(II).

References

1. Andreeva I. I., Rodman L. S. Botanika. Moscow: Kolos, 2005. 528 p.
2. Kostenko Ye. Ye. Khimiko-analitychni vlastyvosti sulfoftaleinovykh barvnykiv, immobilizovanykh na anioniti AV-17×8 ta yikh vykorystannia v analizi kharchovykh obiektiv // Metody ta obiekty khim. analizu. 2011. Vol. 6, Issue 1-2. P. 56–61.
3. Kostenko Ye. Ye. Khimiko-analitychni vlastyvosti azobarvnykiv, immobilizovanykh na anioniti AV-17×8, ta vykorystannia yikh v analizi kharchovykh obiektiv // Ukraynskyi khymycheskyi zhurnal. 2011. Vol. 77, Issue 8. P. 107–115.

4. Shtokalo M. Y., Kostenko E. E. Zastosuvannia metodu tverdofaznoi spektrofotometriyi v analizi kharchovykh materialiv // Visti Akademiyi inzhenernykh nauk Ukrainy. 2002. Issue 1 (14). P. 36–41.
5. Kostenko E. E., Shtokalo M. Y. Tverdofaznaya spektrofotometriya–effektivnyy metod opredeleniya tyazhelyh metallov v pishchevyh ob'ektah // Zhurnal analiticheskoy himii. 2004. Vol. 59, Issue 12. P. 1276–1281.
6. Brykina G. D., Krysina L. S., Ivanov V. M. Tverdofaznaya spektrofotometriya // Zhurnal analiticheskoy himii.1988. Vol. 43, Issue 9. P. 1547–1552.
7. Brykina G. D., Marchenko D. Yu., Shpigun O. A. Tverdofaznaya spektrofotometriya // Zhurnal analiticheskoy himii. 1995. Vol. 50, Issue 5. P. 484–491.
8. Hibrydni metody vyznachennia kadmiu(II) ta sumy vazhkykh metaliv immobilizovanym na sylikaheli brombenztiazo / Zaporozhets O. A., Ishchenko M. V., Suchova K. O., Meshcheriakova V. V. // Tezy dop. VI Vseukr. Konf. «Suchasni problemy khimiyi». Kyiv, 2005. P. 173.
9. Zaporozhec O. A., Cyukalo L. E. Test-opredelenie svinca i cinka v vode s ispol'zovaniem immobilizovannogo na kremnezeme ksilenolovogo oranzhevogo // Zhurnal analiticheskoy himii. 2004. Vol. 59, Issue 4. P. 434–439.
10. Zaporozhets O. A., Ivanko L. S., Kachan I. A. Tverdofaznyi reahent na osnovi molibdofosfornoi heteropolikysloty dlia sorbtsiyno-spektroskopichnoho vyznachennia askorbinovoi kysloty // Voprosy himii i him.tekhnologii. 2005. Issue 1. P. 9–13.
11. Kołodyńska D. Polyacrylate anion exchangers in sorption of heavy metal ions with the biodegradable complexing agent // Chemical Engineering Journal. 2009. Vol. 150, Issue 2-3. P. 280–288. doi: 10.1016/j.cej.2008.12.027
12. Mahmoud M. E., Yakout A. A., Osman M. M. Dowex anion exchanger-loaded-baker's yeast as bi-functionalized biosorbents for selective extraction of anionic and cationic mercury(II) species // Journal of Hazardous Materials. 2009. Vol. 164, Issue 2-3. P. 1036–1044. doi: 10.1016/j.jhazmat.2008.09.017
13. Preparation and characteristics of quaternary amino anion exchanger from wheat residue / Gao B.-Y., Xu X., Wang Y., Yue Q.-Y., Xu X.-M. // Journal of Hazardous Materials. 2009. Vol. 165, Issue 1-3. P. 461–468. doi: 10.1016/j.jhazmat.2008.10.014
14. Kołodyńska D., Hubicka H., Hubick Z. Studies of application of monodisperse anion exchangers in sorption of heavy metal complexes with IDS // Desalination. 2009. Vol. 239, Issue 1-3. P. 216–228. doi: 10.1016/j.desal.2008.02.024
15. Anirudhan T. S., Jalajamony S., Suchithra P. S. Improved performance of a cellulose-based anion exchanger with tertiary amine functionality for the adsorption of chromium(VI) from aqueous solutions // Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2009. Vol. 335, Issue 1-3. P. 107–113. doi: 10.1016/j.colsurfa.2008.10.035
16. Wawrzkiewicz M., Hubicki Z. Removal of tartrazine from aqueous solutions by strongly basic polystyrene anion exchange resins // Journal of Hazardous Materials. 2009. Vol. 164, Issue 2-3. P. 502–509. doi: 10.1016/j.jhazmat.2008.08.021
17. Wawrzkiewicz M., Hubicki Z. Equilibrium and kinetic studies on the adsorption of acidic dye by the gel anion exchanger // Journal of Hazardous Materials. 2009. Vol. 172, Issue 2-3. P. 868–874. doi: 10.1016/j.jhazmat.2009.07.069
18. Predstavlenie rezul'tatov himicheskogo analiza (rekomendacii IUPAC 1994 g.) // Zhurn. analit. him. 1998. Vol. 53, Issue 9. P. 999–1008.