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COMPLEX STANDARDIZATION OF SILICA–MULTIHERBAL NANODISPERSED PHYTOSIL PREPARATIONS

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Number of dietary supplements under the trade name of Phytosils based on fumed silica as enterosorbent and highly dispersed native medicinal plants in various combinations and ratio aimed on specific therapeutic action were developed by the authors. Essential bioactive components of Phytosils are plant polyphenols known for their antiallergenic, antiatherogenic, antiinflammatory, antimicrobial, antioxidant, antithrombotic, cardioprotective and vasodilatory effects which are attributed mainly to their antioxidant activity. Therefore, the value of antioxidant activity in relation to total phenolic content could be used for the standardization of these new herbal dietary supplements. A simple, rapid and sensitive spectrophotometric method for the determination of total antioxidant activity of herbal products has been developed and tested on seven Phytosil multiherbal dietary supplements. The method was based on the reducing of yellow (λ'_{max}=268 nm, λ_{max}''=298 nm) copper(II) tetrabenzo-[b,f,j,n][1,5,9,13]-tetraazacyclohexadecine complex ($CuTAAB^{2+}$) by natural antioxidants with formation of blue (λ_{max} = 660–712 nm) copper(I) complex $CuTAAB^{+}$. It has been shown that total antioxidant activity of Phytosil dietary supplements strongly correlates to their total phenolic content (all r^2 values ≥ 0.960) confirming that phenolic compounds are dominant antioxidant components in these preparations. It can be concluded that antioxidant activity values determined by the proposed $CuTAAB^{2+}$ reducing method and total phenolic content determined at optimized wavelength can be used for good quality assurance and standardization of Phytosil dietary supplements and other multiherbal preparations.

Keywords: *herbal products, natural antioxidants, antioxidant activity, cupric complex, total phenolic content*

INTRODUCTION

Nowadays, the oxidative stress defined as the shift in the balance between oxidants and antioxidants in favor of oxidants is considered to be significant contributing factor to aging and various diseases [1, 2]. In recent decades antioxidants were found to be responsible for the defense mechanism of the organism against pathologies associated to the attack of free radicals. Thus, the intake of plant derived antioxidants, including phenolic compounds known to protect organisms against harmful effects of oxygen radicals [3–5], increased sharply. Another reason of the popularity of phenols as natural antioxidant protectors is their availability and safety [6]. Phenolic compounds are widespread in all plants and demonstrate anti-allergenic, antiatherogenic, anti-inflammatory, antimicrobial, antioxidant, anti-thrombotic, cardioprotective and vasodilatory effects [5–7] which are attributed mainly to their antioxidant activity (AOA) [2, 8].

Seven dietary supplements under the trade name of Phytosils contain fumed silica as enterosorbent and 22 highly dispersed native medicinal plants in various combinations and ratio aimed on specific therapeutic action. As well as for other plant products [9–13], the value of antioxidant activity in relation to total phenolic content was expected to be promising for the standardization of Phytosils.

The interest to AOA determination has started to grow rapidly since 1990 when antioxidant role of plant polyphenols as essential constituents of many natural foodstuffs and beverages was approved. Numerous volumetric, spectrophotometric, chemiluminescent, fluorescent, electrochemical and other methods have been proposed [14–21]. According to their mechanisms all AOA assays could be divided into hydrogen atom transfer (HAT) and electron

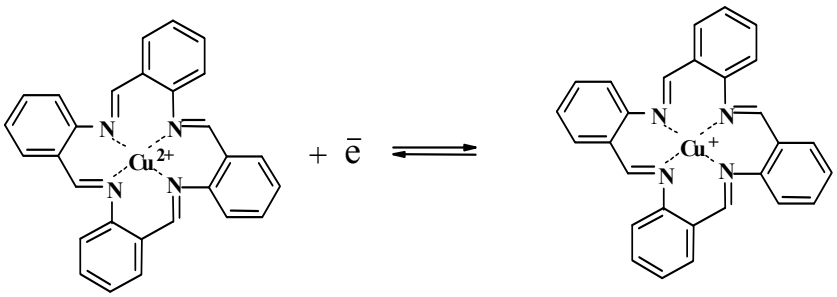
transfer (ET) assays. Most of HAT assays are based on competition kinetics in the reaction of antioxidant and substrate with peroxyl radicals thermally generated through the decomposition of azo compounds. ET assays (ABTS/TEAC, DPPH, FRAP, CUPRAC) detect the capability of an antioxidant to transfer one electron to reduce any chromogenic compound including metals, carbonyls, and radicals by measuring a color change of a redox reagent. Advantages and disadvantages of HAT and ET AOA assays are summarized in the review by Prior *et al.* [19].

The most commonly used spectrophotometric ET assays are based on the capability of antioxidants to scavenge the long-life intensely colored radicals $ABTS^{\bullet+}$ (2,2`-azinobis(3-ethylbenzthiazoline-6-sulfonic acid) cation) [22] and DPPH (2,2-diphenyl-1-picrylhydrazyl) [23] resulting in loss of their absorbance at 734 or 515 nm, respectively. The decoloration process is monitored by a spectrophotometer. The percentage of remaining $ABTS^{\bullet+}$ and DPPH is proportional to the antioxidant concentration [10, 11, 24, 25]. All radical scavenging methods require complex stages over different prolonged periods of time.

Another group of AOA assays monitors the capability of antioxidant compounds to reduce metal ions in the presence of photometric reagents. Ferric Reducing Antioxidant Power (FRAP) method is based on the reducing of Fe^{3+}–2,4,6-tripyridyl-*s*-triazine (TPTZ) complex to intense blue colored product Fe^{2+}–TPTZ. The increase in absorbance at λ_{max} = 595 nm measured within 4–25 min, depending on the phenolic composition, is proportional to the antioxidant activity of the sample [26–29]. This method has a number of limitations, in particular, it is not capable to detect slowly reactive phenolic compounds. In addition, the reagent has to be prepared of three solutions (TPTZ, ferric chloride and acetate buffer) and after that can be used only for seven days even if stored at 4 °C in the dark.

Similar AOA assays are based on the reducing of Cu(II) to Cu(I) which forms charge-transfer complexes with bathocuproine (λ_{max} = 490 nm) (Bioxytech AOP-490 assay [30]) or neocuproine (λ_{max} = 450 nm) (CUPRAC method [31–33]). Absorbance is measured at fixed time (4–30 min). As well as FRAP assays, copper reducing assays have problems with selecting an appropriate reaction time because of the complicated mixture of antioxidants in the sample.

Despite the large number of the methods of AOA evaluation in botanicals reported, new simple and time-saving assays are still of great need. Earlier we have proposed the method of AOA evaluation for individual organic reductants (ascorbic acid and analgin) [34] and herbal products [35] using the redox reaction of tetrabenzo-[b,f,j,n][1,5,9,13]-tetraazacyclo-hexadecine–Cu(II) complex ($CuTAAB^{2+}$) immobilized on silica gel. Its interaction with natural reductants is accompanied with a contrasting color change:



$CuTAAB^{2+}$
yellow, λ'_{max}=268 nm, λ_{max}''=298 nm

$CuTAAB^{+}$
blue, λ_{max} = 660–712 nm

Absorbance of the solid-phase reagent increased proportionally to the total antioxidant activity of the sample solution. For quercetin used as a standard antioxidant the range of linear response was observed in the wide range of concentrations (40–240 μg/mL) [35]. This test method is simple, with «drop and measure» procedure applied, and provides good statistical parameters. However, it needs accurate time monitoring (10 min/sample), and requires additional equipment for spectrophotometric measurements.

The objectives of the present work were: (1) to develop more sensitive and time-saving spectrophotometric method of AOA evaluation using $CuTAAB(NO_3)_2$ in the solutions; (2) to optimize the wavelength choice in the spectrophotometric determination of total phenolic content based on the complexation with Al(III); (3) to study the correlation between total antioxidant activity evaluated by the method developed and total phenolic content of seven Phytosil dietary supplements to confirm that phenolic constituents are responsible for their antioxidant activity.

MATERIALS AND METHODS

Chemicals. All chemicals and reagents were of analytical grade or purest quality purchased from Sigma Chemical Co., Merck, Aldrich Chemical Co. and Fluka. $CuTAAB(NO_3)_2$ was synthesized by tetramerization of *o*-aminobenzaldehyde in the presence of Cu(II) nitrate [36]. Standard solutions of $CuTAAB(NO_3)_2$, caffeic acid derivatives and flavonoids were prepared by dissolving their weighted amounts in warm freshly distilled water, with the exception of quercetin that was preliminarily dissolved in small volume of ethanol.

Multicomponent herbal dietary supplements under the trade name Phytosil (Table 1) were obtained according to [37] .

Table 1. General characteristics of the Phytosil dietary supplements

Sample	SiO_2, %	Plant name	Medicinally used parts	Use
1	2	3	4	5
Phytosil-A	50	*Rhamnus cathartica L.*	fruit	to normalize the function
		Tussilago farfara L	leaf	of the immune system at
		Ribes nigrum (blackcurrant)	fruit	allergy
		Thymus serpyllum L.	aerial parts	
		Rósa majális	fruit	
Phytosil-G	30	*Achillea millefolium* (yarrow)	aerial parts	for human parasite and
		Rhamnus cathartica L.	fruit	worm intestinal cleanse
		*Mentha piperita (*peppermint)	leaf	and for development of
		Tanacetum vulgare L. (tansy)	flower	effective anti-parasite
		Matricaria chamomilla	flower	immunity
		Ribes nigrum (blackcurrant)	fruit	
		Thymus serpyllum L.	aerial parts	
Phytosil-D	10	*Zea-mays L.*	corn columns	to regulate and normalize
		Melissa officinalis	leaf	the function of the
		Petrus Jacobus Stevus	leaf	gastrointestinal tract
		Prunus spinosa L. (blackthorn)	fruit	
		Thymus serpyllum L.	aerial parts	
		Vaccinium myrtillus L.	fruit	
		Cichórium íntybus	root	
Phytosil-K	10	*Aronia melanocarpa*	fruit	for improving the
		Crataegus oxyacantha	fruit	functioning of the
		Citrus limon	fruit	cardiovascular system
		Mentha piperita (peppermint)	leaf	
		Ribes nigrum (blackcurrant)	fruit	
		Rósa majális	fruit	
Phytosil-L	25	*Vaccinium vitis-idaea*	leaf	to improve the respiratory
		Sambucus nigra L.	flower	functioning at chronic and
		Rhamnus cathartica L.	fruit	acute respiratory diseases
		Tilia cordata	flower	
		Tussilago farfara L. (foalfoot)	leaf	
		Ribes nigrum (blackcurrant)	fruit	
		Salvia officinalis	leaf	

1	2	3	4	5
Phytosil-P	40	*Achillea millefolium* (yarrow)	aerial parts	to normalize the functions
		Rhamnus cathartica L.	fruit	of the liver and gall
		Zea mays L.	corn columns	bladder
		Mentha piperita (peppermint)	leaf	
		Ribes nigrum (blackcurrant)	fruit	
		Viola tricolor L.	aerial parts	
		Rósa majális	fruit	
		Cichórium íntybus	root	
Phytosil-R	20	*Achillea millefolium* (yarrow)	aerial parts	to prevent translocation of
		Rhamnus cathartica L.	fruit	infectious-toxic agents in
		*Mentha piperita (*peppermint)	leaf	the internal environment
		Matricaria chamomilla	flower	after gastrointestinal
		Ribes nigrum (blackcurrant)	fruit	operations
		Prunus spinosa L. (blackthorn)	fruit	
		Thymus serpyllum L.	aerial parts	

Apparatus. Absorption spectra were registered using a UV/Vis spectrophotometer Specord M-40 (Carl Zeiss Jena, Germany).

Sample preparation. Phytosil samples were dried to constant weight in desiccant at room temperature (~23 °C). 0.200 g (m) of each sample was extracted with 20 mL of freshly distilled water at 95–100 °C for 2 h in a water bath. After cooling the extracts were filtered and diluted with water to the final volume of 25 mL (V_1). Phytosil extracts obtained in this way were stored at 4 °C until use within 24 h. Each sample was prepared in triplicate.

RESULTS AND DISCUSSION

UV-vision spectra of all Phytosil extracts are similar and have the absorbance maxima in the range from 280 to 289 nm and from 323 to 328 nm (Fig. 1).

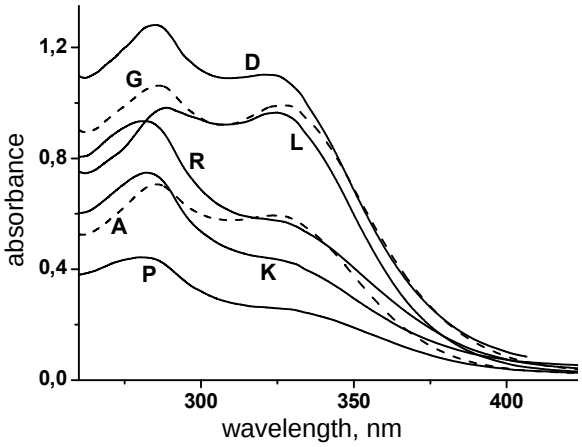


Fig. 1. Absorption spectra of Phytosil-A, -G, -D, -K, -L, -P, -R water extracts (10 %, v/v), l = 1 cm

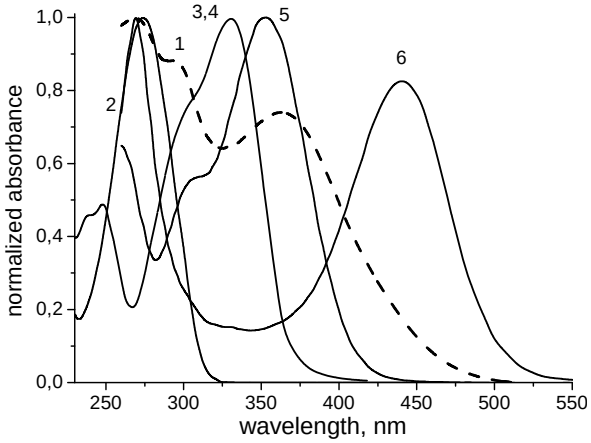


Fig. 2. Normalized absorption spectra of Phytosil-A (*1*), cinnamic (*2*), caffeic (*3*), ferulic (*4*), chicoric (*5*) acids, and quercetin (*6*); pH = 4.5

Fig. 2 presents normalized absorption spectra of Phytosil-A extract (curve 1) in comparison with some phenolic acids (curves 2–5) and flavonoid quercetin (curve 6) in aqueous solutions. As seen from Figs. 1 and 2, such polyphenols predominate in the medicinal plants of Phytosil dietary supplements. That is why caffeic acid (CA) and quercetin (Q) have been chosen as standard compounds for quantitative analysis of Phytosils.

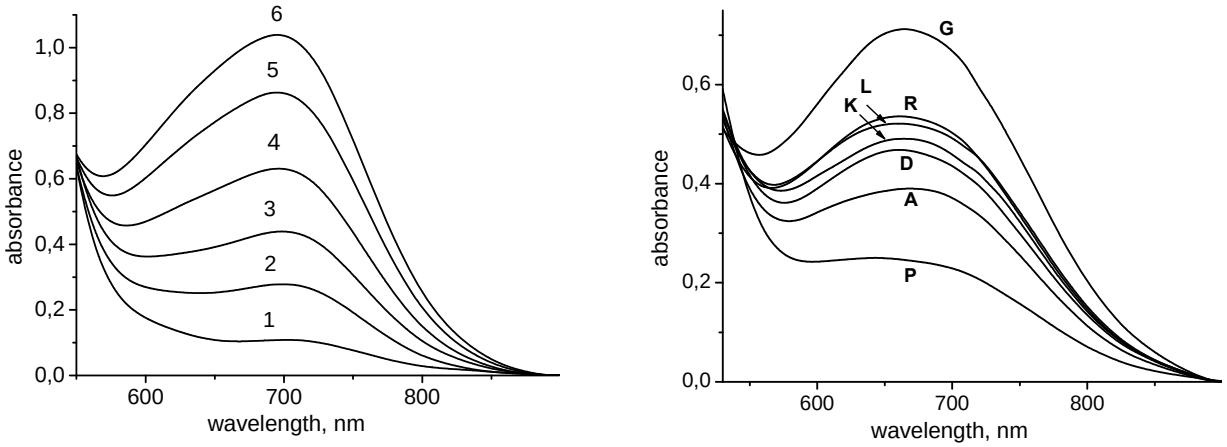
Total antioxidant activity. It has been found experimentally that Phytosil dietary supplements containing different medicinally used parts of 22 plants, as well as individual phenolic

compounds (caffeic acid and quercetin), can reduce $CuTAAB^{2+}$ complex to $CuTAAB^{+}$. In ethanol solution (water:ethanol = 1:1, v/v) $CuTAAB^{+}$ formed is soluble, and its spectrum is characterized by a maximum at λ_{max} = 695 nm. Contrary, in aqueous solution this complex forms highly dispersed suspension which absorbance recorded at λ_{max} = 660 nm is proportional to total antioxidant activity. This is illustrated in Fig. 3 *a*, *b*, representing spectra of $CuTAAB^{+}$ formed at various concentrations of quercetin in water-ethanol solution and in the water extracts of different Phytosils, respectively.

Experimentally AOA of Phytosil extracts was determined in ethanol (technique I) and water (technique II) under the optimized reaction conditions such as reagent concentration, pH, and oxidation time.

Technique I. An aliquot 0.5 mL (V_2) of Phytosil water extract, 2.5 mL of ethanol, 0.8 mL of 2.0 mmol/L $CuTAAB(NO_3)_2$ solution, 0.2 mL of $NaHCO_3$–Na_2CO_3 buffer solution (pH 10.7±0.2) were placed into the 5 mL (V_3) volumetric flask, and distilled water was added up to the mark. The absorbance (A) of the sample was measured immediately after component mixing at λ_{max} = 695 nm against a reagent blank.

Technique II. The determination of Phytosil extract antioxidant activity was carried out as described above without ethanol adding. The absorbance (A) of $CuTAAB(NO_3)$ suspension formed in aqueous solution was recorded immediately after component mixing and vigorous shaking at λ_{max} = 660 nm against a reagent blank.



a *b*

Fig. 3. Visible spectra of $CuTAAB^{+}$ produced as a result of $CuTAAB^{2+}$ reducing with varying concentrations of quercetin in water-ethanol (1:1, v/v) solution (*a*) and 10-diluted water extracts of different Phytosils (*b*). *l*=1 cm. C_Q (mg/ml) = 0.0014 (*1*); 0.004 (*2*); 0.007 (*3*); 0.012 (*4*); 0.017 (*5*); 0.021 (*6*). Letters from A to R correspond to the names of Phytosils

The calibration curves for total AOA were obtained using caffeic acid and quercetin standard solutions under the same procedure as described above. The values of Phytosil extract antioxidant activity expressed as C_{CA}, mg/mL or C_Q, mg/mL were calculated from the equations of the calibration curves (Table 2).

Calibration curves for the determination of caffeic acid and quercetin antioxidant activity in ethanol and aqueous solutions were linearized with high correlation coefficients $r^2 > 0.97$ (Table 2) what indicates that both assays are applicable. However, AOA assay in aqueous medium is some more preferable ($r^2 > 0.988$), and therefore, total antioxidant activity of Phytosil dietary supplements was determined by $CuTAAB^{2+}$ reducing method using technique II. For quercetin and caffeic acid the linear response was observed in the range of concentrations (1–30) μg/mL and (2–40) μg/mL, respectively.

Total antioxidant activity of Phytosils expressed as caffeic acid or quercetin equivalents

in mg CAE/g dw and QE/g dw was calculated as follows:

$$\text{Total antioxidant activity} = C_{CA(Q)}\, V_1\, V_3 / V_2\, m$$

Table 2. The equations of the calibration curves «absorbance – the antioxidant concentration » for the spectrophotometry determination of Phytosil extracts antioxidant activity

Medium	Standard compound	λ, nm	$A=(a\pm\Delta a)+(b\pm\Delta b)C$(mg/mL)	*n*	r^2
water-ethanol (1:1, v/v)	caffeic acid	695	(0.03±0.07)+(28.6±3.2) C_{CA}	8	0.971
	quercetin		(0.00±0.01)+(46.2±3.3) C_Q	8	0.985
water	caffeic acid	660	(0.09±0.05)+(27.4±2.2) C_{CA}	8	0.988
	quercetin		(0.01±0.02)+(28.5±0.3) C_Q	6	0.997

Table 3. Total antioxidant activity of Phytosil dietary supplements

	Phytosil	A	G	D	K	L	P	R
Antioxidant activity	mg CAE/g dw	13.9±0.4	17.6±0.7	29.1±1.6	18.8±0.7	20.1±1.4	6.4±0.8	19.6±1.6
	mg QE/g dw	17.4±0.4	20.8±0.7	31.9±1.6	22.1±0.7	23.3±1.4	10.2±0.8	22.8±1.6

It has been found (Table 3) that total antioxidant activity values of Phytosils vary widely and ranged from 6.4 to 29.1 mg CAE/g dw and from 10.2 to 31.9 mg QE/g dw. It is noteworthy that these results cannot be explained only by differences in percentage of plant components in dietary supplements (Table 1), since the correlation coefficient between plant content and antioxidant activity is found to be only $r^2 = 0.571$.

Total phenolic content. Phytosil extracts are characterized by rather intensive absorbance (Fig. 1) due to polyphenols. Addition of $AlCl_3$ to Phytosil extracts causes bathochromic shift of their spectra (Fig. 4) as a result of Al(III) complexation with phenolic compounds.

Total phenolic content of Phytosil extracts was determined by the spectrophotometric assays based on their self absorbances (technique III) and on the complexation with Al(III) [38] (technique IV):

Technique III. Into the 10 mL (V_3) volumetric flask an aliquot (1 mL) (V_2) of Phytosil extract was placed; pH was adjusted to pH 4.5 using 10 % NH_4Cl solution, and then distilled water was added up to the mark. The solution was mixed and its absorbance (A) was measured against distilled water in 1 cm cell.

Technique IV. Into the 10 mL (V_3) volumetric flask an aliquot (1 mL) (V_2) of Phytosil extract and 2.5 mL of 0.5 mol/L $AlCl_3$ solution (pH 2.0) were placed; pH was adjusted to pH 4.5 using 10 % NH_4Cl solution, and then distilled water was added up to the mark. To avoid the interference of Phytosil extract own coloration, its absorbance was measured in 1 cm cell against the blank solution containing all the same components as the analyzed one, except $AlCl_3$.

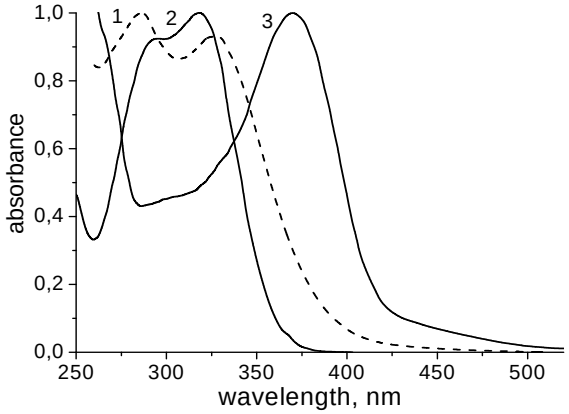


Fig. 4. Normalized absorption spectra of Phytosil-A (*1*), caffeic acid (*2*), and quercetin (*3*) in the presence of Al(III) at pH = 4.5

For the correct determination of total quantity of related compounds with close spectral characteristics, such as phenolic compounds, the choice of the optimal wavelength of absorbance recording is principally important. Since antioxidant activity

of Phytosils is provided mainly by natural phenols, the absorption spectra of their water extracts alone (technique III) and in the presence of Al(III) (technique IV) were compared with the antioxidant activity found spectrophotometrically using $CuTAAB^{2+}$ reducing method to find conditions of the best correlation. For this purpose the absorbances of Phytosil extracts were measured at the wavelengths λ_i considering that $\lambda_i = (255 + 5n)$ nm (where $n = 0, 1, 2, 3 \ldots 100$) and plotted against antioxidant activities of the corresponding samples. Some correlations and correlation coefficients ($r^2_{\lambda i}$) are presented in Fig. 5 for example.

Dependences of $r^2_{\lambda i}$ on the wavelength (Fig. 6) show that correlation coefficients have the highest values at 280 nm (Fig. 6, curve 1) and 285 nm (Fig. 6, curve 2). Therefore, these wavelengths were chosen as optimal for determination of total phenol concentration in Phytosil extracts by techniques III and IV, respectively.

The calibration curves "absorbance versus phenolic concentration" were obtained using caffeic acid and quercetin standard solutions under the same procedure as described above. Total phenolic content of Phytosil extract was calculated from the equations of these calibration curves (Table 4) and expressed as caffeic acid concentration (C_{CA}, mg/mL) or quercetin concentration (C_Q, mg/mL).

Total phenolic contents found spectrophotometrically by measuring absorbance of Phytosil extracts alone and in the presence of Al(III) (Table 5) also vary widely and also do not depend strongly on plant percentage as is indicated by low correlation coefficient found ($r^2 = 0.420$). Probably, the diversity of phenolic compounds and their different distribution in plants play significant role along with the proportion of plant components.

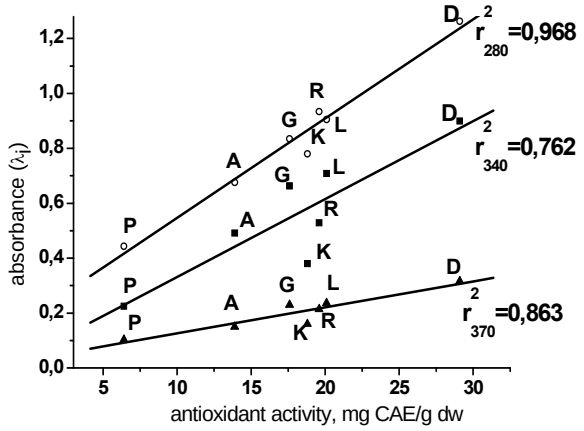


Fig. 5. Relationship between absorbances of Phytosil extracts at the wavelengths λ_i and antioxidant activity of Phytosils dietary supplements expressed as caffeic acid equivalents

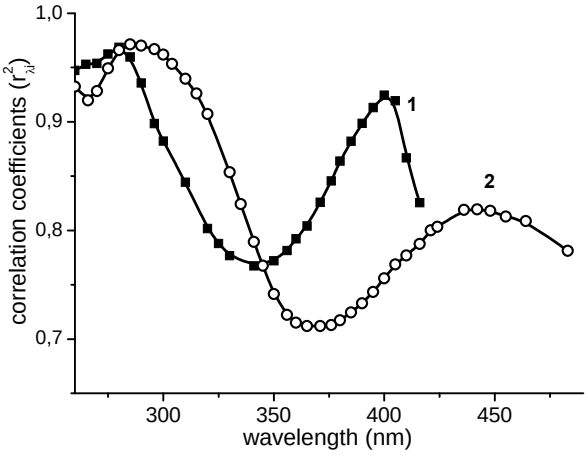


Fig. 6. Correlation coefficients $r^2_{\lambda i}$ versus wavelength λ_i for Phytosil water extracts alone (*1*) and in the presence (*2*) of Al(III)

Table 4. Equations of the calibration curves of standard phenolic compounds for the spectrophotometric determination of total phenolic content of Phytosil extracts

Standard compound	Reagent	λ, nm	$A=(a\pm\Delta a)+(b\pm\Delta b)\ C$(mg/mL)	r^2 (n=6)
caffeic acid	–	285	$(0.01\pm0.02)+(57.5\pm1.9)\ C_{CA}$	0.9995
quercetin	–	285	$(0.00\pm0.01)+(24.6\pm0.7)\ C_Q$	0.9998
caffeic acid	Al(III)	300	$(0.01\pm0.02)+(55.4\pm1.7)\ C_{CA}$	0.9989
quercetin	Al(III)	300	$(0.01\pm0.01)+(22.2\pm0.7)\ C_Q$	0.9996

Table 5. Total phenolic content of Phytosil dietary supplements (P = 0.95, n = 6)

Sample	Spectrophotometric assay			
	Self-absorbance (technique I)		Complexation with Al (III) (technique II)	
	mg CAE/g dw	mg QE/g dw	mg CAE/g dw	mg QE/g dw
Phytosil-A	12.4±0.7	31.9±1.4	12.3±0.7	30.8±1.5
Phytosil-G	16.1±0.9	40.64±2.5	17.09±1.0	40.54±2.9
Phytosil-D	26.7±1.4	67.6±2.9	27.3±1.5	62.8±3.5
Phytosil-K	13.3±0.9	35.3±2.1	13.3±1.1	35.4±2.0
Phytosil-L	17.9±1.1	43.7±2.2	16.0±1.0	41.1±2.3
Phytosil-P	7.6±0.4	19.1±0.9	7.1±0.4	17.7±0.7
Phytosil-R	18.1±0.9	42.1±3.1	17.8±0.8	44.3±1.9

Fig. 7 represents the relationship between total antioxidant activity and total phenolic content of Phytosil dietary supplements expressed as caffeic acid (Fig. 7, curves 1) or quercetin (Fig. 7, curves 2) equivalents in mg CAE/g dw (1), mg QE/g dw (2) and demonstrates high correlation coefficients in all cases (r^2 = 0.9626–0.9780). Such strong correlations confirm that phenolic compounds are dominant antioxidant components in Phytosil dietary supplements studied, and that $CuTAAB^{2+}$ reducing method proposed can be successfully applied for the direct monitoring of the antioxidant activity of different herbal products. This method provides high accuracy, it is precise, reproducible, sensitive, time-saving, and easy-to-handle. Aqueous solution of $CuTAAB(NO_3)_2$ is stable at storage during at least several years.

High correlation coefficients also confirm applicability of our approach to the choise of the wavelengths for the spectrophotometric determination of total phenolic content of multi-herbal Phytosil preparations using caffeic acid and quercetin as standards.

In addition, almost identical correlation coefficients for spectrophotometric determination of total phenolic content by measuring absorption of Phytosil water extracts alone and in the presence of aluminum(III) enable this simple self-absorbance method to be also used for the standardization of these preparations.

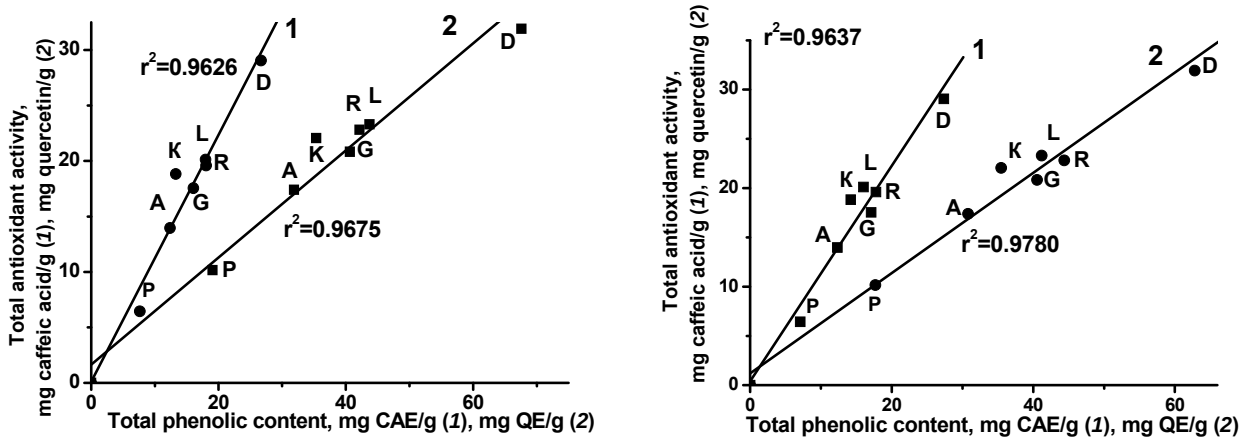


Fig. 7. Relationship between total antioxidant activity and total phenolic content of Phytosil dietary supplements found by measuring absorption of Phytosil extracts alone (*a*) and in the presence of Al(III) (*b*). Letters from A to R correspond to the names of Phytosils

It can be concluded that values of AOA determined by the proposed $CuTAAB^{2+}$ reducing method and total phenolic content determined spectrophotometrically at optimum wavelength can be used for good quality assurance and standardization of Phytosil dietary supplements and other multiherbal preparations.

Новий підхід до комплексної стандартизації нанодисперсних багатокомпонентних рослинних препаратів на основі кремнезему

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Розроблено простий, швидкий і чутливий спектрофотометричний метод для визначення загальної антиоксидантної активності рослинних препаратів і випробувано його на семи багатокомпонентних дієтичних добавках Фітосил, що містять лікарські рослини і кремнезем. Метод базується на відновленні забарвленного комплекса тетрабензо[b,f,j,n][1,5,9,13]тетраазациклогексадецин купрум(II) нітрату природними антиоксидантами. Було показано, що загальна антиоксидантна активність біологічно активних добавок Фітосил строго корелює з загальним вмістом фенольних сполук (всі величини $r^2 \geq 0.960$), підтверджуючи, що фенольні сполуки є основними антиоксидантними компонентами в цих препаратах.

***Ключові слова**: лікарські рослини, антиоксидантна активність, комплекс двовалентної міді, загальний вміст фенольних сполук*

Новый подход к комплексной стандартизации нанодисперсных многокомпонентных растительных препаратов на основе кремнезема

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Разработан простой, быстрый и чувствительный спектрофотометрический метод для определения общей антиоксидантной активности растительных препаратов; он опробован на семи многокомпонентных диетических добавках Фитосил, содержащих лекарственные растения и кремнезем. Метод основан на восстановлении окрашенного комплекса тетрабензо [b, f, j, n] [1,5,9,13] тетраазациклогексадецин купрум (II) нитрата природными антиоксидантами. Показано, что общая антиоксидантная активность диетических добавок Фитосил строго коррелирует с общим содержанием фенольных соединений (все величины $r^2 \geq 0.960$), подтверждая, что фенольные соединения являются основными антиоксидантными компонентами в этих препаратах.

***Ключевые слова:** лекарственные растения, антиоксидантная активность, комплекс двухвалентной меди, общее содержание фенольных соединений*

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