Original Research Article: full paper

(2016), «EUREKA: Life Sciences»
Number 3

STABILITY AND MORPHOLOGICAL CHARACTERISTICS OF LIPID-MAGNETITE SUSPENSIONS

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Abstract

The study of stability of lipid-magnetite suspensions (LMS) was carried out using photometry and electronic microscopy. All suspensions are rather stable in time. The best results in stability were demonstrated by suspensions with ratio Fe_3O_4:SAS=0,02:0,35 g or 0,04 mass %:0,70 mass % and 0,025:0,35 g or 0,05 mass %:0,70 mass %. The sizes of magnetite particles from SAS were determined as – <d>~76 nm.

It was established, that with time (0–48,0 hours) and growth of wave length (210–1000 nm) is observed the gradual increase of transmission coefficient from 25 % (210 nm) to 71,9 % (1000 nm) at 0 hours of suspension ageing; from 27,5 % (210 nm) to 81,2 % (1000 nm) at maximal time of suspension ageing (48 hours).

There parameters of LMS were determined: concentration of particles – $N=1{,}43\cdot10^{12}$ cm^{-3}, in 48 hours concentration decreased by 20 % ($N=1{,}19\cdot10^{12}$ cm^{-3}); r=38 nm, n=1,48, κ=0,01. The function of particles distribution by sizes is rather narrow and symmetric that certifies the system of synthesized nanoparticles as homogenous with low degree of polydispersity.

Ultraviolet spectrums of LMS and their components were fixed and analyzed. Comparison of transmission spectrums of suspensions with different degree of dilution testifies to the chemical identity of samples.

There were studied kinetic dependencies of transmission coefficient for suspensions with different magnetite concentration (Fe_{gen}), on which base was calculated the effective radius of particles of stabilized magnetite: 76–168 nm. The mean radius of particles in lipid suspension of magnetite without stabilizer (r_{eff})=400 nm. Visually LMS manifested the high aggregative stability with high sedimentation time 48 hours.

It was established, that LMS can be used as biologically active and feed additives with complex effect: manifest antioxidant activity, are the source of easily assimilated iron, improve quality and increase storage terms of fat-containing products. Thus, introduction of LMS in foodstuff improves its quality, nutritive and biological value.

Keywords: magnetite, photometry, lipid-magnetite suspension, morphology, effective mean radius, function of particles distribution by sizes, surface active substance (SAS), aggregative and sedimentation stability.

DOI: 10.21303/2504-5695.2016.00143

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1. Introduction

The important problem, solved by food industry, is the widening of assortment of production with raised nutritive value and long storage term and also economy of deficient types of raw material [1].

As biologically active additive that has antioxidant effect and is a source of easily assimilated iron [2] the offered magnetite – double oxide of bi- and trivalent ferum ($FeO \cdot Fe_2O_3$) [3].

The uniqueness of magnetite properties allows recommend Fe_3O_4 as feed additive of complex effect in lipid-magnetite suspensions (LMS) [4–7].

That is why creation of LMS stable in time; analysis of process of sedimentation and determination of their morphologic characteristics is a topical and important problem.

2. Materials and methods of research

At getting suspensions was used the ultra-thin magnetite (with particles size 30–60 nm), synthesized according to the method of co-precipitation of salts of bi- and trivalent ferum in alkaline medium [8]. According to this method, magnetite is received at mixing of water solutions of iron salts (II) and (III) with concentrated water solution of hydroxide ammonium (25 %) with further washing by water.

In the study was used the sunflower oil, refined and deodorized according to SSTU 4492:2005; unrefined corn oil SSTU 8808-2003 "Corn oil. Technical conditions (SSTU 8808-2000. IDT)"; Soy unrefined oil SSTU 4534:2006 "Soy oil. Technical conditions"; pig fat of SSTU 25292-82; beef fat, SSTU 1288-41; unrefined salomas for margarine industry TC 9145-181-00334534-96, TC 15.4-13304871-005:2005; surrogate of milk fat "Vioil – milk fat 3" TC 15.4-13304871-005:2005, SSTU 53796-2010; cakes fat "Shortening" TC U 15.4-00373758:022-2006; SAS (monoacylglycerol) Dimodan HP.

On the **Fig. 1** are given the following lipids: oils (soy, corn, sunflower); salomas; fats (pig, beef and cakes: "Vioil – milk fat 3" and "Shortening"), **Fig. 1.**

Fig. 1. Studied lipids: in glass bottles – oils (soy, corn, sunflower); in plastic package – salomas and cakes fats "Vioil – milk fat3" and "Shortening"); unpackaged – animal fats (pig and beef)

Lipid-magnetite suspensions (LMS) were received by technology [6].

The study of stability and concentration of suspensions, morphological features of particles was carried out using spectrophotometry (spectrometer Spekol 11) ("Milaform" production-service center of trial laboratory equipment, Russia), PE-5400 UV ("Ecochem" Company, Russia) and electronic microscopy (transmission electric microscope (TEM) JSM-820 (JEOL firm, Japan).

2. 1. Experimental procedures

The method of determination of stability and morphological characteristics of lipid-magnetite suspensions is based on analysis of weakening spectrum of suspension with nanoparticles. There is measured the dependence of transmission coefficient T of cell with suspension from the wave length λ of optic radiation that passes through the cell. Spectrophotometric method is based on the Buger-Lambert-Beer law:

$$I = I_0 e^{-\alpha l}, \quad (1)$$

where I_0 – intensity of incident light, I – intensity of light, passed through the cell, l – thickness of suspension layer in cell (1,0 cm), α – coefficient of light weakening.

Transmission coefficient T is defined by the formula:

$$T = \frac{I}{I_0}, \quad (2)$$

where I_0 – intensity of incident light, I – intensity of light, passed through the cell, T – transmission coefficient.

Weakening coefficient α is connected with transmission coefficient T by the next formula:

$$\alpha = -\frac{\ln T}{l}, \quad (3)$$

where l – thickness of suspension layer in cell (1,0 cm), T – transmission coefficient.

If the unit of medium volume includes N equal particles, weakening coefficient can be determined as following (4):

$$\alpha(N, r, m, \lambda) = N\pi r^2 Q(r, m, \lambda), \quad (4)$$

where r – particle radius, m=n–iκ, n – refraction index, κ – absorption index, λ – wave length in medium that surrounds particle, Q – weakening effectiveness factor. The last parameter indicates what part of energy is emitted (diffused and absorbed) by the unitary particle from the radiation beam incident on medium.

If medium contains particles of the different sizes, the formula (4) is transformed into (5):

$$\alpha(N, r, m, \lambda) = N\int_0^\infty Q(r, m, \lambda)\pi r^2 f(r)d(r), \quad (5)$$

where f (r) – function that describes the particles distribution by sizes.

At solving such tasks it is usually thought, that particles are spherical. In many cases it is true – for example, in emulsions. If particles have incorrect form, the characteristics of light, diffused with a large number of chaotically oriented particles do not essentially differ from the ones of light, diffused with spherical particles.

The spherical weakening effectiveness factor can be calculated by formulas, known from diffraction theory [9, 10]:

$$Q = \frac{2}{\rho^2}\sum_{l=1}^{\infty}(2l+1)\mathrm{Re}\,(a_l + b_l), \quad (6)$$

where

$$a_l = \frac{m\psi_l(m\rho)\psi_l'(\rho) - \psi_l'(m\rho)\psi_l(\rho)}{m\psi_l(m\rho)\zeta_l'(\rho) - \psi_l'(m\rho)\zeta_l(\rho)}, \quad (7)$$

$$b_l = \frac{m\psi_l'(m\rho)\psi_l(\rho) - \psi_l(m\rho)\psi_l'(\rho)}{m\psi_l'(m\rho)\zeta_l(\rho) - \psi_l(m\rho)\zeta_l'(\rho)}, \quad (8)$$

where $\psi_l(\rho)$ and $\zeta_l(\rho)$ Bessel-Riccati functions, $\rho=2\pi r/\lambda$.

After experimental determination of the spectrum of light weakening by the medium with particles and solution of integral equation (5), the function of particles distribution by sizes f(r), their complex refraction index m and concentration N can be found.

The object of research was the soy-magnetite suspension with refraction index 1,48. The cell with studied suspension was placed in spectrometer Spekol 11 ("Milaform" production-service center of trial laboratory equipment, Russia), PE-5400 UV ("Ecochem" Company, Russia).

The transmission spectrums of diluted suspensions (concentration 4,85–38,9 mg/l, diluter ethanol or isooctane were analyzed in regime of spectrum measurement (210–1000 nm) and kinetic measurements on the same wave length (600 nm) and duration of suspension ageing 6000 s. For assessment of time of suspension sedimentation t_{sed} the received kinetic dependences of transmission coefficient from time (or area of dependences) were linearly approximated. The mean effective radius of particles was determined by the following equation [11]:

$$r_{eff} = \sqrt{9\eta\upsilon_{sed} / 2(\rho - \rho_0)g}, \quad (9)$$

where η – viscosity of disperse medium $1510\cdot10^{-3}$ Pa·s (for water $1\cdot10^{-3}$ Pa·s), ρ – mean actual density of particles, consisted of magnetite and monoacylglycerol (near 4,15 g/cm^3), ρ_0 – density of disperse medium (in our case soy oil – 0,925 g/cm^3), υ_{sed} – sedimentation speed, found as $\upsilon_{sed}=H/t_{sed}$. Here H – height of liquid column in cell is equal 2 cm, g=9,8 m/s^2 – gravitation acceleration of free fall.

Weakening coefficient was calculated by formula (3). Numerous mathematical methods allow solve integral equation (5) and find function f(r) and parameters r, n, κ, N. But at the same time it is necessary to solve the problem of search of the minimum of function of the four variables. As far as such function can have many minimums, the absolutely incorrect result can be found. At the same time the weakening effectiveness factor is described by the bulky expressions (6)–(8), so the time, necessary for solution of equation (5) using the modern computers is very long (tens of minutes). That is why some simplifications are used in setting and solution of the problem.

– It was thought, that particles distribution by sizes is described by the following formula:

$$f(r) = \frac{\beta^\mu}{G(\mu+1)} r^\mu e^{-\beta r}, \quad (10)$$

where f (r) – gamma – function, μ and β – parameters of function.

In the works [12–14] it was noted, that this function well describes the distribution of micro- and nanoparticles by sizes in emulsions and suspensions. The values of μ and β parameters are determined by the position of function maximum r_{max} and its width Δr by equation (10):

$$\mu = \left(\frac{2{,}48 r_{max}}{\Delta r}\right)^2, \ \beta = \left(\frac{2{,}48}{\Delta r}\right)^2 r_{max}.$$

In such case the task is reduced to determination of such values of μ and β parameters, at which the equation (5) is correct.

– To decrease the time of calculations it was used the approximated expression for the weakening effectiveness factor. There is a series of mathematical expressions [12–14], each of which is correct for the certain conditions – very big or very little (comparing with wave length) particles,

ideally reflecting particles or ones with a small refraction index. For nanoparticles ($\rho<<1$) it is expedient to use expansion of the expression (6) in series by degrees ρ [9, 11]:

$$Q = -\mathrm{Im}\left[4\rho\frac{m^2-1}{m^2+2}+\frac{4}{15}\rho^3\left(\frac{m^2-1}{m^2+2}\right)^2\times\frac{m^4+27m^2+38}{2m^2+3}\right]+\mathrm{Re}\left[\frac{8}{3}\rho^4\left(\frac{m^2-1}{m^2+2}\right)^2\right].$$

At $\rho<0,6$, n=1.2 ... 2, $\kappa<0,75$ error of this series does not exceed 2 %.

– Integral (5) is substituted by sum:

$$\alpha(N,r,m,\lambda) = N\pi\delta r\sum_j Q(r,m,\lambda)r_j^2 f\left(r_j\right).$$

Index j in this expression changes from null to j_{max} that determines the number of node points on the integration area. The distance between node points is equal:

$$\delta_r = \frac{r_{max}-r_{min}}{j_{max}},$$

where r_{min}=0, r_{max}=0,05 mcm (50 nm) – diapason of possible values of radiuses of particles, measured in experiment. It also shortens the calculations time by 20–30 %.

Processing of experimental data was realized in two stages:

1. With the help of equation (4) was determined the mean particles radius r and parameters n, κ and N. The function was formed for it:

$$S(r,n,\kappa,N) = \sum_{i=0}^{i_{max}}\left[N\pi r^2 Q(r,n,\kappa,\lambda_i)-\alpha_i\right]^2,$$

where λ_i – wave lengths, at which was measured weakening coefficient α_i, and with the help of the least square method were determined the values of parameters r, n, κ, N, at which function (r, n, κ, N) has minimum.

The found values of these parameters essentially depend on initial approximations that are used to find minimum. That is why the additional control was realized over the form of graphs with experimental points α_i and curve α (r, n, κ, N, λ), that must passes near these points. The value of function S (r, n, κ, N) was also controlled; it also depends on the initial approximation and must be the least.

2. The received data were used in Mathcad program for determination of parameters β and μ in function of particles distribution by sizes. The studied function was:

$$S(r_{max},\Delta r) = \sum_{i=0}^{i_{max}}\left[N\pi\delta r\sum_j Q(r,m,\lambda_i)r_j^2 f(r_{max},\Delta r,r_j)-\alpha_i\right]^2$$

and the values of parameters r_{max} and r, at which it is minimal, were determined.

For calculations and analysis of experimental data are also needed the values α_i and λ_i, determined by formulas (11), (12):

$$\alpha_i = -\ln(T_i/100)/l, \quad (11)$$

$$\lambda_i = \lambda_0/n_0, \quad (12)$$

where λ_0 – wave length in air, mcm (nm); λ_i – wave length in fat (oil), mcm, (nm); l – size parameter (thickness) of cell (1 cm or 10^{-2} m); T – transmission coefficient, %; n_0=1,48 – refraction index of disperse medium (soy oil), determined experimentally.

Determination of size of the system of synthesized magnetite particles, stabilized by the surface active substance (momoacylglycerol) was carried out by transmission electric microscope (TEM) JSM-820 (JEOL firm, Japan) with possible magnification up to 150000 times. Electronic microscopy it is a direct method of the study of powder particles system. It not only allows recognize the separate particles in their totality and determine their morphological features but also gives idea about the state of surface particles.

The examples for electronic-microscopic studies were prepared by suspension method. In this method of humid preparation of particles the sample is created directly from the studied powder. The films, received by spreading of drop of collodion solution in amylacetate on water surface, were used as backing. The particles of magnetite material, added in composition, were dispersed using ultrasound dispersant USD ("Eco", Ukraine) (ν=35 kHz, t~20 min). Such method of samples preparation does not influence the particle surface – does not remove it that allows receive with the help of microdiffraction the necessary information about crystal structure of the separate particles. In the result of studies were received electronic microphotos, processed by AutoCad 2014 and MathCad 2014 programs.

3. Results of research

The results of measurement of transmission coefficient (T, %) depending on light wave length (λ, nm) in time (ratio Fe_3O_4:SAS=0,05:0,70 mass %; suspension concentration 29,25 mg/l) are given in the **Table 1**

Table 1

Results of measurement of transmission coefficient (T, %) depending on light wave length (λ, nm) in time for soy-magnetite suspension

λ, nm	Transmission coefficient T, %					ΔT, %
	Suspension ageing time τ, hours					
	0	0,5	1,0	24,0	48,0	
210	25	25,6	26,3	26,9	27,5	10,0
250	23	24,1	25,2	26,7	27,2	18,3
300	26	26,5	27,3	28,5	29,9	15,0
350	28,2	29,7	31,4	32,9	34,4	21,9
400	29	30,6	31,9	33,8	35,7	23,1
450	33,1	34,4	35,7	37,3	39,5	19,3
500	31,5	33,8	34,5	35,6	38	20,6
550	30,5	32,6	33,3	34,5	36,8	20,6
600	48,6	50,7	52,8	58,2	63,5	30,7
650	54,6	55,8	58,4	63,5	68,7	25,8
700	57,8	59,6	62,5	66,7	71,3	23,4
750	58,5	60,3	64,6	68,3	72	23,1
800	61,2	62,9	66,5	70,3	74,6	21,9
850	64,5	66,2	68,6	72,5	76,1	18,0
900	69,6	70,9	73,4	76,3	80	14,9
950	71,6	72,3	73,9	76,9	80,9	13,0
1000	71,9	72,5	73,7	77	81, 2	12,9

The typical form of experimental dependence α(λ) for soy-magnetite suspension is given on the **Fig. 2.** At that α_i and λ_i were determined by formula (11), (12) n_0=1,48 – experimentally determined index of disperse medium (soy oil) refraction.

Theoretical curve is built by approximation of experimental data of weakening coefficient dependence from the wave length.

Using equation (4) the mean radius of particles r and parameters n, κ and N were determined. For that the function was formed:

$$S(r, n, \kappa, N) = \sum_{i=0}^{i_{max}} \left[N\pi r^2 Q(r, n, \kappa, \lambda_i) - \alpha_i \right]^2,$$

where λ_i – length of waves, at which the weakening coefficient α_i was measured.

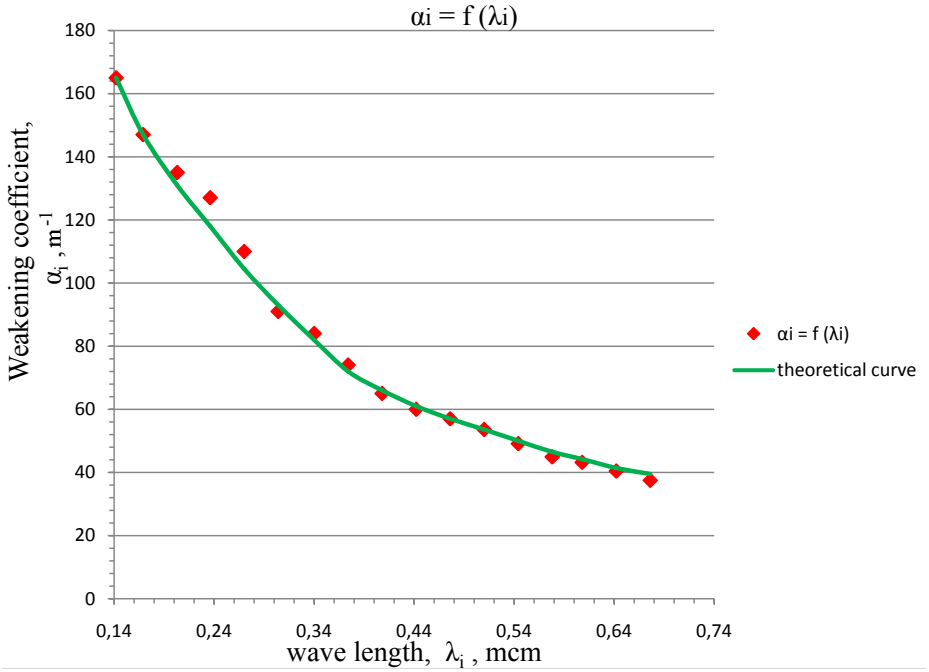

Fig. 2. Dependence of light weakening coefficient (α, m^{-1}) in soy-magnetite suspension from wave length (λ, mcm)

The value of parameters, n, κ, N, at which the function S (r, n, κ, N) has minimum was determined by the least squares method. Calculation of minimization function was carried out using Mathcad.

Then the additional control was realized over the form of graphs with experimental points α_i and curve α (r, n, κ, N, λ), that must pass near these points **Fig. 1**. The value of function S (r, n, κ, N) was also controlled; it also depends on the initial approximation and must be the least.

The following values were received for the studied soy-magnetite suspension: r=38 nm, n=1,48, κ=0,01, $N=1,43\times10^{12}$ m^{-3}.

The values of refraction and absorption indices are satisfactorily agreed with additional data for magnetite: in wave length diapason from 0,4 to 0,8 mcm its refraction index changes from 1,9 to 1,7, and absorption index – from 0,1 to 0,01.

The received data were used in MathCAD for determination of parameters β and μ in function of particles distribution by sizes.

The **Fig. 3** is presented the graph of normalized function of particles distribution f(r) by size.

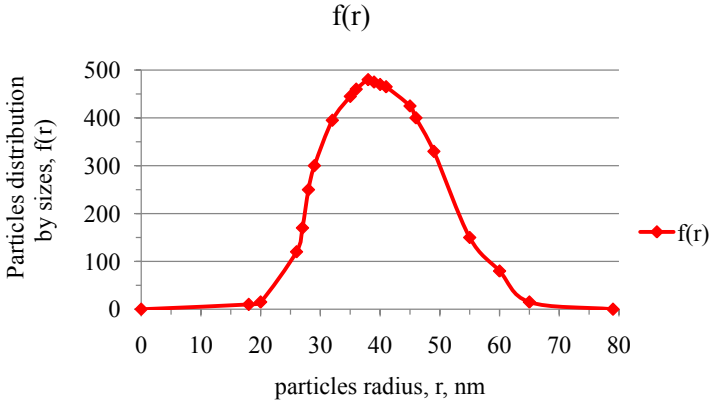

Fig. 3. Particles distribution in soy-magnetite suspension SMS) by sizes, measured by optical method

For comparison on the **Fig. 4** is given histogram of magnetite particles distribution in soy-magnetite suspension (SMS) by size, received in the result of processing of observations using electronic microscope, that demonstrates that the results of both methods are agreed.

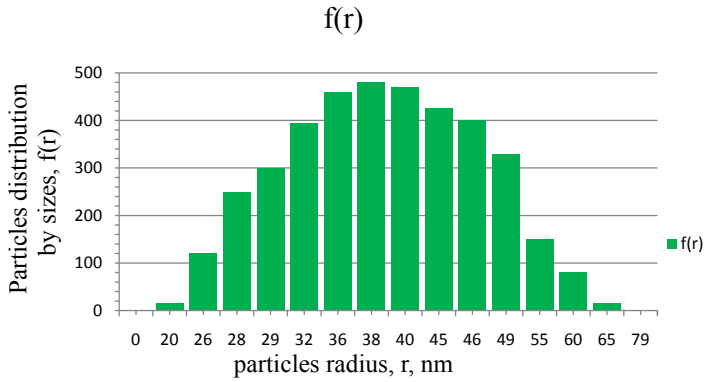

Fig. 4. Histogram of magnetite particles distribution in soy-magnetite suspension (SMS) by size, received in the result of processing of observations using electronic microscope

Knowing the particles size, found their concentration in suspension were found. In the **Table 2** are given the results of study of changes of particles number (concentration) in 1 cm³ of suspension during 45 days.

Table 2

Number of particles in 1cm³ of soy-magnetite suspension (SMS)

SMS ageing time, τ, hour	Number of magnetite particles in 1 cm³ of suspension
0	$1{,}43 \cdot 10^{12}$
0,5	$1{,}42 \cdot 10^{12}$
1,0	$1{,}40 \cdot 10^{12}$
24,0	$1{,}34 \cdot 10^{12}$
48,0	$1{,}23 \cdot 10^{12}$
1080,0	$1{,}19 \cdot 10^{12}$

Concentration (particles number in 1 cm³) at preparation of suspension is equal $N=1{,}43 \cdot 10^{12}$ cm^{-3} (**Table 2**).

According to experimental data, given in the **Table 2**, it is possible to make conclusion as to sedimentation, aggregative stability and dispersity of LMS (on example of SMS). LMS are stable in time – for 1080 hours particles concentration in suspension decreases by 16,8 %; and for 48 hours by 14 % – from $1{,}43 \cdot 10^{12}$ to $1{,}19 \cdot 10^{12}$ cm^{-3} (**Table 2**).

The best stability results were demonstrated by suspensions with ratio Fe_3O_4:SAS=0,02 g:0,35 g or 0,04 mass %:0,70 mass % and 0,025:0,35 g or 0,05 mass %:0,70 mass %.

The following values for soy-magnetite suspension (SMS) were determined: diameter of magnetite particles from SAS – 76 nm, n=1,48, κ = 0,01.

It was established, that with time (0–1080,0 hour) and growth of wave length (210–1000 nm) was observed the gradual increase of transmission coefficient from 25 % (210 nm) to 71,9 % (1000 nm) at 0 hours of suspension ageing; from 41,8 % (210 nm) to 88,7 % (1000 nm) at maximal suspension ageing time (1080 hours) (**Tables 3, 4**).

Experimental data on dependence of transmission coefficient (T,%) from the light wave length (λ, nm) for the soy-magnetite suspensions (SMS) of the different composition with different concentration of $Fe_{(gen.)}$ are given in **Tables 3, 4.**

The assessment of aggregative stability was carried out using kinetic measurements.

On the **Fig. 5** are demonstrated kinetic dependencies of transmission coefficient for suspensions with different magnetite concentrations ($Fe_{gen.}$).

Table 3

Dependence of transmission coefficient (T, %) from the light wave length (λ, nm) for the soy-magnetite suspensions (SMS) of the different composition (suspension concentration 4,85 mg/l)

Light wave length (λ, nm)	Fe_3O_4	Monoacylglycerol (MA)	Soy oil, (SO)	Fe_3O_4+MA	Fe_3O_4+SO	MA+SO	Fe_3O_4+MA+SO
200	13	9	5	9	7	10	10
205	22	9	6	11	9	12	10
225	24	10	6	14	13	16	12
230	23	22	9	20	18	19	14
250	25	28	16	26	23	25	20
275	26	31	27	29	27	28	30
300	28	34	30	35	31	32	33
310	29	37	33	39	35	36	36
350	27	42	38	43	39	39	37
360	28	46	42	40	36	44	38
375	27	51	47	44	40	48	42
400	29	56	52	50	48	52	43
450	26	71	65	47	46	54	44
490	25	77	73	43	44	62	42
500	24	80	76	42	43	66	41
540	23	84	80	41	42	71	40
550	34	86	82	47	49	78	45
600	50	89	85	56	58	82	57
650	60	90	86	64	66	85	67
700	65	91	87	72	70	87	72
750	68	92	88	78	76	90	73
800	70	92	89	82	80	92	74
850	71	92	90	82	80	92	75
900	72	92	90	81	79	92	75
950	72	92	90	80	79	91	75
1000	72	92	90	80	79	91	75

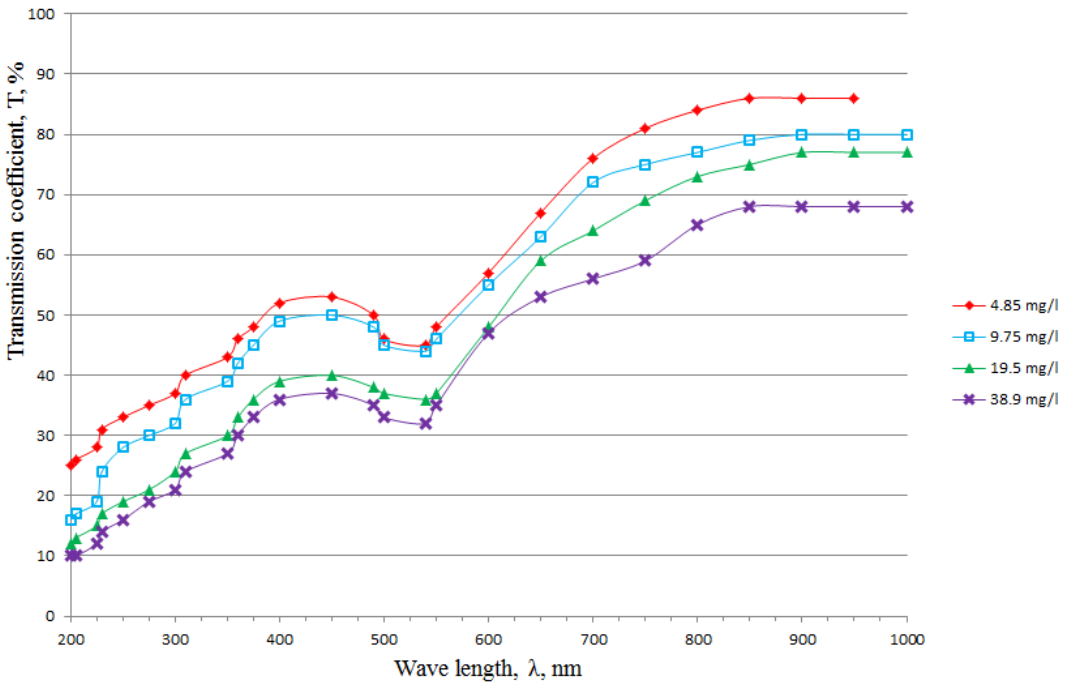

Fig. 5. Dependence of transmission coefficient (T, %) from light wave length (λ, nm) of soy-magnetite suspensions (SMS) of the different concentration

Table 4

Dependence of transmission coefficient (T, %) from the light wave length (λ, nm) for the soy-magnetite suspensions (SMS) of the different concentration

Light wave length, λ, nm	Transmission coefficient T, %			
	$Fe_{gen.}$ In suspension, mg/l			
	4, 85 mg/l	9,75 mg/l	19,5 mg/l	38,9 mg/l
200	25	16	12	10
205	26	17	13	10
225	28	19	15	12
230	31	24	17	14
250	33	28	19	16
275	35	30	21	19
300	37	32	24	21
310	40	36	27	24
350	43	39	30	27
360	46	42	33	30
375	48	45	36	33
400	52	49	39	36
450	53	50	40	37
490	50	48	38	35
500	46	45	37	33
540	45	44	36	32
550	48	46	37	35
600	57	55	48	47
650	67	63	59	53
700	76	72	64	56
750	81	75	69	59
800	84	77	73	65
850	86	79	75	68
900	86	80	77	68
950	86	80	77	68
1000	86	80	77	68

In UV-spectrums (**Tables 3, 4** and **Fig. 5**) are the weak strips of transfer n→π* at 200–210 nm, typical for saturated radicals (monoacylglycerol– MA) and more intense strips of transfer π→π* at 210–230 nm, typical for α, β-unsaturated acyls (soy oil – SO). In magnetite spectrum are observed the wide strips of absorption within 490 and 540 nm, associated with lattice fluctuations of Fe–O– connections in tetra- and octahedral positions of Fe_3O_4. Comparing these curves with dependence of transmission coefficient from the wave length for LMS, can be seen the presence of spectrum features, typical for magnetite, monoacyglycerol and oil (lipid). Comparison of the transmission spectrums of suspensions with the different dilution degree testifies to the chemical identity of samples.

Analysis of kinetic dependences of transmission coefficient for LMS indicates the nonlinear law of change of transmission coefficient for suspensions without stabilizer or with the high content of magnetite (38,9 mg/l), that can be explained by existence of different fractions of magnetite particles and their aggregation. In UV-area of spectrum at the low concentrations is observed the direct proportionality between transmission coefficient and concentration of Fe(gen.), that is absorbing centers Fe_3O_4. The assessment of effective mean radius of particles by sedimentation kinetics gives values 76–168 nm, moreover up to concentration 38,9 mg/l the dependence of (r_{eff}) from C (Fe_{gen}) is nonlinear.

Approximating the received dependence by the straight lines and extrapolating them to T=100 %, the mean effective radius of particles can be assessed. In the **Table 5** are given the temporary dependences of transmission coefficient of studied suspensions on the wave length 600 nm. The received values of sedimentation time and effective mean radius are given in the **Table 6.**

Table 5

Temporary dependences of transmission coefficient (T, %) of soy-magnetite suspensions (SMS) of the different concentration on the light wave length (λ=600 nm)

Suspension ageing time, τ, hours	Transmission coefficient T, %				
	Fe gen. concentration in suspension, mg/l				
	4,85 mg/l	9,75 mg/l	19,5 mg/l	38,9 mg/l	4, 85 mg/l without SAS
0	67	63	59	53	58
1800	68,4	64,8	61,3	56,9	72,7
3600	69,2	66	63,2	64,5	82,7
6000	71,7	67,3	66,9	68,9	89,8

Table 6

Results of calculation of sedimentation time t_{sed} and mean effectice radius of particles r_{eff} at the different suspension concentration

Parameter	$Fe_{gen.}$ concentration, mg/l			
	4,85	9,75	19,5	38,9
$t_{sed,}$ hour	454	228	168	147
$r_{eff,}$ nm	76	92	146	168

According to the data of the **Table 6** can be assessed the mean effective radius of particles in LMS of the different concentration and also aggregative stability of suspensions.

4. Conclusions

All LMS are stable in time – up to 1080 hours. The best stability results were shown by suspensions with ratio Fe_3O_4:SASP=0,02 g:0,35 g or 0,04 mass %:0,70 mass % and 0,025:0,35 g or 0,05 mass %:0,70 mass %. The diameter of magnetite particles with SAS was determined – 76 nm. It was established, that with time (0–48,0 hours) and growth of the wave length (210–1000 nm) was observed the gradual increase of transmission coefficient from 25 % (210 nm) to 71,9 % (1000 nm) at 0 hours of suspension ageing; from 27,5 % (210 nm) to 81,2 % (1000 nm) at maximal time of suspension ageing (48 hours).

There was determined concentration of magnetite particles, stabilized with surface active substance – concentration (number of particles in 1 cm^3) at preparation of suspension is equal $N=1,43 \cdot 10^{12}$ cm^{-3}. It was established the decrease in time of the number of magnetite particles with SAS in 1 cm^3 soy-magnetite suspension: for 48 hours concentration in 1 cm^3 decreased by 20 % – from $1,43 \cdot 10^{12}$ to $1,19 \cdot 10^{12}$ cm^{-3}. The following values were determined for soy-magnetite suspension (SMS): r=38 nm, n=1,48, κ=0,01. The established order of the mean size of particles is <r>~38 nm.

In UV-spectrums are the weak strips of transfer n→π* at 200–210 nm, typical for saturated radicals (monoacylglycerol – MA) and more intense strips of transfer π→π* at 210–230 nm, typical for α, β-unsaturated acyls (soy oil – SO). In magnetite spectrum are observed the wife strips of absorption within 490 and 540 nm, associated with lattice fluctuations of Fe–O– connections in tetra- and octahedral positions of Fe_3O_4.

Comparing these curves with dependence of transmission coefficient from the wave length for LMS, can be seen the presence of spectrum features, typical for magnetite, monoacyglycerol and oil (lipid). Comparison of the transmission spectrums of suspensions with the different dilution degree testifies to the chemical identity of samples.

Analysis of kinetic dependences of transmission coefficient for LMS indicates the nonlinear law of change of transmission coefficient for suspensions without stabilizer or with the high content of magnetite (38,9 mg/l), that can be explained by existence of different fractions of magnetite particles

and their aggregation. In UV-area of spectrum at the low concentrations is observed the direct proportionality between transmission coefficient and concentration of Fe(gen.), that is absorbing centers Fe_3O_4. The assessment of effective mean radius of particles on sedimentation kinetics gives values 76–168 nm, moreover up to concentration 38,9 mg/l the dependence of (r_{eff}) from C (Fe_{gen}) is nonlinear.

Last decades there are actively created the new nanomaterials, elaborated nanotechnologies that find the wide use in the different industrial branches. The modern level of nanotechnologies allows elaborate on the base of magnetite nanoparticles the unique means for pharmacy, medicine, biology, food industry. Their introduction in practice is a base of the modern progress in fields of creation of biologically active, deictic additives; therapeutic and preventive nutrition; diagnostics and therapy, including cellular and gene levels.

So, creation of LMS, stable in time with magnetite nanoparticles; analysis of their sedimentation process; determination of aggregative and sedimentation stability of magnitive suspensions, sizes of stabilized particles Fe_3O_4, functions of distribution by sizes is a topical and important task.

Magnetite has magnetic properties, so the further study of magnetic properties of magnetite nanoparticles in lipid-magnetite suspensions is interesting.

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